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WATER QUALITY OF THE OHIO RIVER, LOUISVILLE., KENTUCKY - EVANSVILLE, INDIANA

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Water Quality of the Ohio River
Louisville, Ky. - Evansville, Ind.

Prepared by the
National Field Investigations Center

for
Division of Technical Support
Federal Water Quality Administration
United States Department of the Interior

Cincinnati, Ohio
September, 1970

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LOUISVILLE, KENTUCKY-EVANSVILLE, INDIANA

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PREFACE

State standards considered in this report were those applicable at the time of preparation.

Since the preparation of the report, the State of Indiana has upgraded its standards, and on September 29, 1970, an official agreement was reached between the Federal Water Quality Administration and the State of Kentucky concerning water quality standards.

SUMMARY AND CONCLUSIONS

During October 1967 a water quality survey was made on the Ohio River between Louisville, Kentucky and Evansville, Indiana, to determine bacteriological quality including the causes of high coliform densities, and the probable causes of reported fish flesh tainting. The study of the off-flavor of fish was extended to January 1969 to gain additional information about specific waste sources.

GENERAL

1. Estimated average river discharges during the survey at Louisville and Evansville were 46,200 and 50,800 cfs respectively.
2. Water temperatures averaged 20° C in the Louisville reach and 19° C in the Evansville reach.
3. Dissolved oxygen (DO) concentrations were higher at all river sampling stations than the Indiana and Kentucky water quality standards for fish and aquatic life which now specify 5.0 mg/l for 16 hours of any day and not less than 3.0 mg/l at any time.
4. Bacterial pollution from inadequately treated sewage creates a health hazard in the Ohio River from

Louisville, Kentucky to Evansville, Indiana. The geometric mean total coliform densities ranged from 15,300 to 740,000 MF/100 ml, and the geometric mean fecal coliform densities ranged from 700 to 89,000 MF/100 ml.

During the survey, the total coliform density at all stations exceeded state standards for body contact recreation by 15 to 740 times; the state standards for domestic raw water supplies were exceeded by 3 to 148 times. Both the Indiana and Kentucky total coliform standards specify maxima of 1,000 per 100 ml for body contact recreation and 5,000 per 100 ml for domestic raw water supply sources. The Indiana total coliform standard for non-body contact recreation is 5,000 per 100 ml. Pathogenic Salmonella were isolated at 9 out of 10 sampling stations.

5. Plankton in the Ohio River is the base of the food web; it can be detrimental when it imparts tastes and odors to domestic water supplies. Plankton concentrations were usually less than 1500/ml,

which is considered to be a low density at the flow which occurred during the survey. At higher flows it would be expected that the plankton population would decrease as the result of increased silt action on the algal population and by dilution.

Factors other than nitrogen and phosphorus apparently control the plankton population because these elements were present in sufficient quantities (1.6 mg/l inorganic nitrogen and 0.06 soluble phosphorus) to promote abundant growth.

6. Sludge on the Ohio River bed from organic pollution decreased gamefish food organisms, increased pollution-tolerant sludgeworms, and removed dissolved oxygen from the water by decomposition.
7. Complaints from commercial fishermen received by the Evansville Field Station of the Ohio Basin Region, and subsequent interviews with commercial fishermen in both Indiana and Kentucky concerning the unmarketability of fish from the Ohio River,

indicate that fish captured downstream from Louisville and Brandenburg, Kentucky are unpalatable.

8. The Ohio River contained sufficient taste producing substances to cause catfish to be of unacceptable quality (unpalatable) in July, 1968 from Louisville to Evansville, a distance of 190 miles, and from Louisville to Owensboro, a distance of 150 miles, in October, 1968.

SPECIFIC

1. Within the Louisville to Brandenburg reach, municipal waste from Louisville, Kentucky, New Albany, Jeffersonville and Clarksville, Indiana, and from industrial sources pollute the Ohio River.
   a. The geometric mean total coliform density increased from 1,640 MF/100 ml upstream from Louisville to 740,000 MF/100 ml 6 miles downstream from Louisville, and 396,000 MF/100 ml 13.7 miles downstream.
   b. The geometric mean fecal coliform density increased from 130 MF/100 ml upstream from Louisville to 89,000 MF/100 ml 6 miles

downstream from Louisville, and 39,000 MF/100 ml 13.7 miles downstream.

c. Pathogenic Salmonella were isolated near the Louisville Water Company intake.

d. There was little lateral mixing between the Louisville Sewage Treatment Plant effluent and the Ohio River. Settleable solids formed a sludge bank along the Kentucky shore that was estimated to be 100 feet wide, 6 inches deep and 7.5 miles long.

e. Kinds of stream bed animals decreased from 8 to 3 in the 7 mile reach bracketing Louisville, Kentucky; slime growths, Sphaerotilus natans, were attached to the river bottom and floated in the water along the Kentucky shore downstream from the Louisville sewage treatment plant; the number of pollution tolerant stream bed organisms was greatest along the Kentucky shore of the Ohio River.

f. Historically, during a 1914-1915 survey, 56 percent of the bottom organisms downstream from the

Louisville treatment plant were not tolerant towards organic wastes. Behind McAlpine Dam, the bottom organism population and composition is now essentially unchanged from that found in 1914-1915. Now, increased organic pollution, over that present in 1915, is indicated in the 3-mile reach downstream from the Louisville treatment plant because no bottom organisms were found that were sensitive to organic wastes.

g. Stream bed animal kinds were reduced from 7 upstream to 4 downstream from the discharge of Olin Mathieson Chemical Corporation at Brandenburg, Kentucky. Pollution tolerant bottom organisms along the Kentucky bank increased from 34 to 75 per square foot. A maximum population of 290 sludgeworms per square foot was present 5 miles downstream from Brandenburg (Station 7). Along the Kentucky bank for 20 miles, pollution tolerant sludgeworms were more numerous downstream from the Olin Mathieson Chemical Corporation than upstream.

b. Channel catfish held in cages for 2 days and submitted frozen to professional taste panelists were used to assess the degree of off-flavor acquired in the exposed time period. This test established the presence (X) of both off-flavor and acute toxicity as determined from test fish mortalities in cages.

	Off-Flavor	Toxicity
1. Mead Container Wastes, Louisville, Ky.	X	X
2. Louisville Sewage Treatment Plant Effluent	X	
3. Reynolds Metals Company Wastes, Louisville, Ky.		X
4. E. I. duPont de Nemours and Co. Wastes, Louisville, Ky.	X	X
5. American Synthetic Rubber Corp., Louisville, Ky.	X	
6. Stauffer Chemical Company, Louisville, Ky.	X	X
7. Olin Mathieson Chemical Corp., Brandenburg, Ky.	X	X

2. Municipal wastes from the Owensboro, Kentucky Sewage Treatment Plant increased the total and fecal coliform densities downstream from the waste discharge.
3. Near the Evansville, Indiana water intake the total coliform density had a geometric mean of 27,700 MF/100 ml; calculations indicate that Louisville, Kentucky was the source of 49 percent of these coliform bacteria and that Owensboro was the source of 51 percent. Pathogenic Salmonella were isolated near the Evansville water supply intake.
4. The Salt River, tributary to the Ohio River between Louisville and Brandenburg, Kentucky, was extremely polluted at its mouth. It supported only 3 kinds of bottom organisms, 92 percent of which were pollution-tolerant. Geometric mean total and fecal coliform densities at the mouth were 1,640,000 MF/100 ml and 112,000 MF/100 ml respectively.

STANDARDS VIOLATIONS

1. The State of Indiana aquatic life standard states, "There shall be no substances which impart unpalatable flavor to food fish, or result in noticeable offensive odors in the vicinity of the water . . . . at any point in the stream except for areas immediately adjacent to outfalls. In such areas, cognizance will be given to opportunities for the admixture of waste effluents with river water." The off-flavor of fish caused by discharges in the Louisville and Brandenburg areas was present in the Ohio River for 190 miles, thus negating the exclusion clause.

   Wastes from Mead Container, Louisville sewage treatment plants, E. I. DuPont de Nemours and Company, American Synthetic Rubber Corporation, Stauffer Chemical Company, and Olin Mathieson Chemical Corporation, contribute off-flavors to fish, making them unpalatable.

2. Both Indiana and Kentucky have minimal water quality standards applicable to all waters at all places and at all times. These are:

   a. "Free from substances attributable to municipal, industrial or other discharges or agricultural practices that will settle to form putrescent or otherwise objectionable sludge deposits."

Sludge deposits were found downstream from the Louisville sewage treatment plant. This condition should be corrected upon completion of plant alterations.

b. "Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges or agricultural practices in amounts sufficient to be unsightly or deleterious."

Discharges of the wastes from the American Synthetic Rubber Corporation contained or produced floating pieces of "sponge rubber" material.

c. "Free from materials attributable to municipal, industrial or other discharges or agricultural practices producing color, odor or other conditions in such degree as to create a nuisance."

This standard was violated by the discharges of Mead Container, Louisville sewage treatment plant, E. I. duPont de Nemours and Company, American Synthetic Rubber Corporation, Stauffer Chemical Company, and Olin Mathieson Chemical Corporation. Channel catfish were unpalatable downstream beyond the immediate vicinity of these discharges.

d. "Free from substances attributable to municipal, industrial or other discharges or agricultural practices in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life."

The discharges from Mead Container, Reynolds Metals Company, E. I. duPont de Nemours and Company, Stauffer Chemical Company and Olin Mathieson Chemical Corporation were toxic to fish in 48 hours at least 300 feet downstream from the respective discharges.

INTRODUCTION

This report is based on a field survey conducted at the request of, and in cooperation with, the Ohio Basin Region, *Federal Water Pollution Control Administration, from October 2 to 13, 1967 and fish studies which continued until January, 1969.

The study was primarily designed: (1) to determine the bacteriological quality of the Ohio River and the waste sources causing high coliform densities from the Louisville, Kentucky - New Albany, Indiana metropolitan area to Evansville, Indiana; (2) to determine the probable causes of reported fish flesh tainting; and (3) to determine existing water quality. Biochemical oxygen demand, dissolved oxygen, suspended solids, and the plant nutrients, nitrogen and phosphorus, were determined and assessments of the bacteriological and biological conditions were made.

*throughout this report reference is made to Federal Water Pollution Control Administration which is now the Federal Water Quality Administration.

WATER QUALITY STANDARDS AND WATER USES

Both Indiana and Kentucky have submitted water quality standards to the Department of the Interior under provisions contained in the Water Quality Act of 1965 (P.L. 89-234,33 U.S.C. 466 g). Those of Indiana (Appendix A) for the Ohio River have been approved by the Secretary; Kentucky's (Appendix B) have been approved with exceptions.

The present standards of both states for various water uses are basically the criteria proposed by the Ohio River Water Sanitation Commission (ORSANCO), as revised, in May, 1967. The ORSANCO water quality criteria are currently under revision. These revisions may lead to standards modifications by the states along the Ohio River so that all the standards are consistent and in agreement. The present Indiana and Kentucky standards for recreation and aquatic life are used in this report (Table 1). For aquatic life, minimum DO's of 5 mg/l during at least 16 hours a day, with an absolute minimum of 3 mg/l are specified.* Stream temperatures have maximum limits of 93° F in summer with Indiana specifying 60° F in winter and Kentucky 73° F.* Bacteriological standards* for recreational uses differ: Indiana differentiates between partial and whole body contact recreation, while Kentucky

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*Water quality criteria currently under consideration for revision by ORSANCO.

TABLE 1

Comparison of
Indiana & Kentucky Aquatic Life and Recreation Standards for the Ohio River

Constituent or Determination	INDIANA	KENTUCKY
Dissolved Oxygen	Not less than 5.0 mg/l 16 hrs. of any 24-hr. period. Not less than 3.0 mg/l at any time.	Same
pH	Limited to pH 6.0 - 9.0 units, preferably between pH 6.5 - 8.5 units.	Limited to pH 5.0 - 9.0 units, preferably between pH 6.5 - 8.5 units.
Temperature	Not to exceed 93° F. during April through November; not to exceed 60° F. December through March.	Not to exceed 93° F. during May through November; not to exceed 73° F. during December through April.
Coliform bacteria (partial body contact)	Average density not to exceed 5,000 per 100 ml.	None specified
Coliform bacteria (body contact)	Average density not to exceed 1,000 per 100 ml.	Same

has a single recreation standard. The Kentucky recreation standard of an average 1,000 total coliforms per 100 ml is the same as the Indiana body contact recreation standard. Indiana limits the coliform group to 5,000 per 100 ml for partial body contact recreation.

The State of Indiana has classified the waters of the Ohio River for a warm-water fishery, agricultural uses, body contact recreation, and industrial and public water supplies. The Commonwealth of Kentucky adopted a similar classification with the exception of recreation. Kentucky ". . deferred designation of the application of the recreation standards at this time as it applies to the Ohio River."*

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* Anon., Report on Water Quality Criteria and Plan for Implementation. Main Stem of the Ohio River and the Kentucky Tributary Basin Excluding the Waters of the Kentucky, Salt and Green Rivers," Kentucky Water Pollution Control Commission, December, 1966.

THE AREA

The Ohio River originates with the confluence of the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania, and flows south-westerly for 981 miles to Cairo, Illinois, where it joins the Mississippi River. It forms portions of the boundaries between the states of Ohio and West Virginia; Ohio and Kentucky; Indiana and Kentucky; and Illinois and Kentucky.

From the headwaters to the mouth, the riverbed elevation drops 429 feet (about 0.44 ft/mile). Generally the river width varies from less than one-quarter mile, between Pittsburgh, Pennsylvania and Wheeling, West Virginia, to about one mile upstream from McAlpine Dam.

The river is channelized from the headwaters to the mouth. The original system of 46 locks and dams is being replaced by a new system of 19 new high level locks and dams. Primary purposes of the new dams are to improve navigation on the river by increasing the channel depth, reduce the number of lockages required between shipping points, and provide for larger locks to accommodate increased tow sizes. At the time of the survey, two dams were under construction in the survey reach; McAlpine

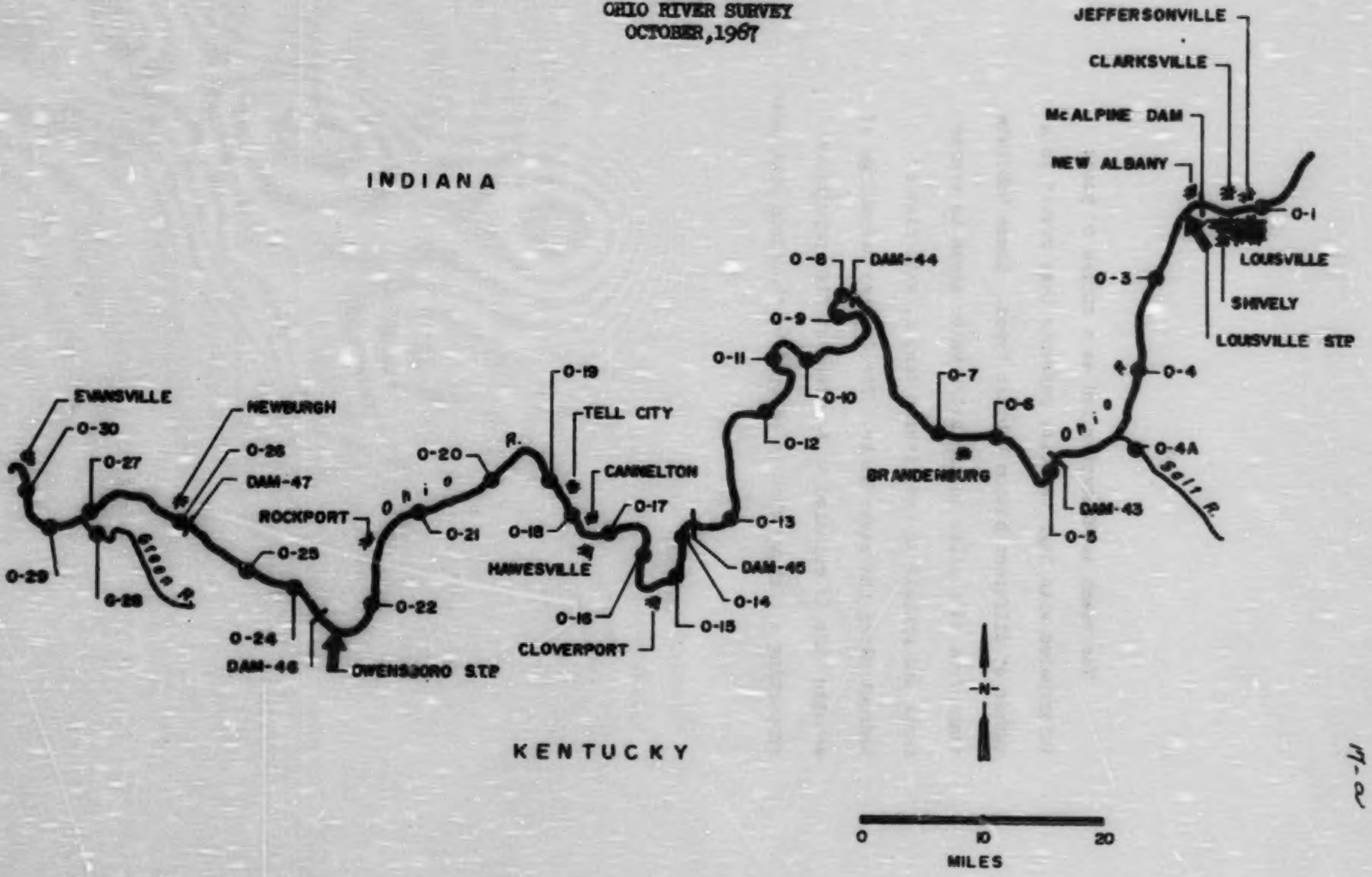
Dam at Louisville had already been completed.

The river is used extensively for public and industrial water supply, navigation, water-related recreation, commercial fishing, and waste disposal. Commercial barges transport materials to cities located along the main stem and larger tributaries. Pleasure boating, especially during the summer months, has increased markedly since 1945.

The 191-mile reach of the river considered in this report extends from Louisville, Kentucky, to Evansville, Indiana (Figure 1). This reach of the river forms a state boundary with Indiana to the north and Kentucky to the south. Six existing low level dams and two high level dams under construction are located here.

Major tributaries entering the Ohio River in this reach are the Salt River and the Green River. The Salt River enters about 24 miles downstream from McAlpine Dam. The Green River joins the Ohio River about seven miles upstream from the Evansville Water Works intake. The Green River is the larger tributary; it is channelized and supports commercial barge traffic.

Figure 1
LOCATION MAP
OHIO RIVER SURVEY
OCTOBER, 1967


JEFFERSONVILLE
CLARKSVILLE
McALPINE DAM
NEW ALBANY
O-1
LOUISVILLE
SHIVELY
LOUISVILLE STP
O-3
O-4
O-4A
Salt R.
Ohio
O-5
DAM-43
O-6
O-7
BRANDENBURG
O-8
DAM-44
O-9
O-10
O-11
O-12
O-13
DAM-45
O-14
O-15
CLOVERPORT
O-16
O-17
CANNELTON
HAWESVILLE
O-18
TELL CITY
O-19
R.
O-20
Ohio
O-21
ROCKPORT
O-22
OWENSBORO STP
DAM-46
O-24
O-25
DAM-47
O-26
NEWBURGH
Green R.
O-27
O-28
O-29
O-30
EVANSVILLE
INDIANA
KENTUCKY
-N-
0
10
20
MILES

17-a

The reach is characterized as a series of pools interspaced with high velocity currents that result in a number of different bottom habitat types. These habitats range from fine silts in the slack water areas to coarse sands and gravels in the river's center, with clay or bedrock along the river banks. The diverse assemblage of aquatic life is climaxed in an abundant fish population supporting a fishery that is enjoyed by thousands each year.

METHODS OF STUDY

CHEMICAL AND BACTERIOLOGICAL SURVEY

The study reach was divided into two sections of about equal lengths; the upstream section consisted of stations 0-1 through 0-13; and the downstream section was comprised of stations 0-14 through 0-30. These 31 stations included the Louisville sewage treatment plant effluent (0-2), the Salt River (0-4A), the Green River (G-28), and the Owensboro treatment plant effluent (0-23) (Appendix F).

Samples from each station, with the exception of stations 0-2 and 0-23, were scheduled for collection twice daily for 10 days. The two daily sampling runs were scheduled to start at daybreak and late morning. The direction of sample collection was alternated between downstream and upstream throughout each of the two survey reaches to obtain samples from each station at various times throughout the day.

Automatic samplers installed at the Owensboro and Louisville sewage treatment plants collected 24-hour composite samples of plant effluents for chemical analyses. Grab samples of the treatment plant effluents were collected for coliform tests twice daily.

Since a lack of lateral mixing was suspected, sampling stations 0-3, 0-4, 0-6, 0-19, 0-22, 0-24, and 0-29 were sampled at quarter points (3 points per cross section) and composited into a single sample. Single mid-channel samples were collected from the remaining stations because the distance downstream from waste discharges or tributaries was sufficient to ensure adequate lateral mixing.

Samples were analyzed for:

a. Temperature
b. pH
c. Total coliform
d. Fecal coliform
e. Salmonella (from "swabs" recovered from 10 selected stations)
f. Dissolved Oxygen
g. BOD (2-day and 5-day at each station; at selected stations using the NH_4Cl carbonaceous test and 2 sets for 20-day BOD's)
h. Nitrogen Series (NO^-_3, total organic and NH_3)
i. Phosphorus Series (total and soluble)
j. Total and volatile suspended solids
k. Turbidity
l. Conductivity

Samples for coliform bacteria and dissolved oxygen analyses were collected on each sampling run, i.e., two samples per station per day. Samples for other analyses were collected once each day and the time of collection was alternated between morning and afternoon.

Separate samples were collected for DO, bacteria, and chemical analyses. The DO and chemical samples were collected at a depth of 5 feet and the bacteriological samples were collected near the surface. All samples were iced in dark coolers to eliminate sunlight effects. Temperature, pH and specific conductance were determined immediately after sample collection. A summary of the chemical and bacteriological data is contained in Appendix H.

Two mobile laboratories were located at the Louisville, Kentucky, sewage treatment plant. Analyses of samples from the upstream section were analyzed in these laboratories. The samples from the downstream section were analyzed at the Evansville, Indiana, Field Station Laboratories. Dissolved oxygen, BOD, pH, turbidity, and coliform analyses were conducted when the samples were delivered to the laboratories. Samples were preserved for later determination of nitrogen, phosphorus, and suspended solids.

BIOLOGICAL STUDY

The biological field survey was also conducted October 2 - 13, 1967. Ninety-one Petersen dredge samples were collected with three samples taken along a river cross-section. Seventy-four surface water samples were collected for algal nutrient analyses and 28 for phytoplankton counts. Twenty-four bottom sediment samples were collected to determine phosphorus, organic nitrogen and organic carbon. At 7 locations in the Louisville area, the rate of oxygen demand by the sediment was determined with an in-situ respirometer.

To determine the compounds contaminating the fish tissue, catfish were purchased from fishermen at Utica, Indiana, West Point, Kentucky, and Leavenworth, Indiana. These fish were held in recirculating water which passed through an activated carbon absorption filter.

In May 1968, a new series of investigations were begun. Channel catfish from Lake Erie were purchased from a live fish dealer and placed in flowing well water ponds for four weeks. The fish were then transported to Louisville, Kentucky and placed in metal mesh baskets at various sites in the Ohio River. Following a five day exposure period, the fish were removed from the baskets, filleted, tagged and frozen with dry ice. The fish were then shipped to a professional taste panel at Oregon State University in Corvallis, Oregon for rating as to the degree of off-flavor and desirability.

In July, 1968, a cooperative investigation involving the Ohio River Valley Water Sanitation Commission, the State of Kentucky, the State of West Virginia Bureau of Commercial Fisheries, and the Federal Water Pollution Control Administration was undertaken to determine the degree of off-flavor of fish throughout the entire Ohio River. Samples were placed at lock and dam sites to obtain results on the general off-flavor trend of fish rather than specific causative effluents. To determine if catfish held in cages would be contaminated with the same degree of off flavor as native fish, native channel catfish were captured from four of the test sites. All of the test fish from this investigation were quick frozen whole and flown to the Bureau of Commercial Fisheries Laboratory in Ann Arbor, Michigan for taste panel testing. The taste panel at the Bureau of Commercial Fisheries Laboratory was used during this portion of the study because this was a cooperative study.

A third test was conducted in October, 1968, which included 32 sites extending from Pittsburgh to Cairo, with 16 of the sites in the Louisville area. The fish from this study were frozen whole and shipped to Ann Arbor for taste evaluation. Sample fish from the intensive Louisville study were split so that fish from the same sample basket were sent to both Corvallis, Oregon and Ann Arbor, Michigan for taste and odor evaluation.

SOURCES OF WASTES

Using the Indiana and Kentucky inventories to augment visits to the various plants, an estimate was made of the discharged municipal waste strength in the reach from Louisville, Kentucky, to Evansville, Indiana (Table 2). This inventory was reviewed by both Indiana and Kentucky.

Of the eight municipalities discharging sewage to the river from Kentucky, two have no treatment while six provide primary treatment. Nine municipalities discharge to the river from Indiana with eight providing primary and one secondary treatment. Kentucky sewage represents 85.8 percent of the total sewered population within the study reach. Discharges from both states represent a sewered population of 555,200; the discharged wastes had a bacterial population equivalent of 2,952,000 and a BOD population equivalent of 717,350.

It was estimated that of the coliform bacterial population equivalents discharged to the Ohio River from municipal sources, Louisville, Kentucky, contributed 90 percent and Owensboro, Kentucky 9.6 percent (Table 2). These two communities together were responsible for 99.6 percent of the coliform bacteria discharged by municipal waste sources.

Table 2

Ohio River: Louisville, Ky. - Evansville, Ind.
Municipal Waste Inventory
October, 1967

Municipality	Type of System(1)	Treatment	Population Served Number	Population Served % of Total	Estimated Population Equivalents Discharged: Bacterial Number	Bacterial % of Total	BOD Number	BOD % of Total	Suspended Solids Number	Suspended Solids % of Total
Kentucky										
Louisville	C	Primary	412,600	74.3	2,627,000(2)	90.21	608,200(2)	84.78	370,200(2)	82.30
Shively	S	Primary & Cl_2	15,200	2.7	760	0.03	10,140	1.42	7,600	1.69
West Point	S	Primary & Cl_2	2,000	0.4	100	-	1,130	0.16	1,000	0.22
Brandenburg	S	Primary & Cl_2	1,500	0.3	75	-	1,000	0.14	750	0.17
Cloverport	S	Primary	1,300	0.2	650	0.02	870	0.12	690	0.15
Hawesville	S	None	900	0.2	900	0.03	900	0.12	900	0.20
Lewisport	S	None	600	0.1	600	0.02	600	0.08	600	0.13
Owensboro	C	Primary & Cl_2	42,500	7.6	278,000(2)	9.55	42,300(2)	5.90	28,900(2)	6.43
Kentucky Total			476,600	85.8	2,908,085	99.86	665,140	92.72	410,600	91.29
Indiana										
Jeffersonville	C	Primary & Cl_2	19,500	3.5	975	0.03	13,000	1.81	9,750	2.17
Clarksville	C	Primary & Cl_2	8,100	1.5	400	0.01	5,400	0.75	4,050	0.90
New Albany	C	Primary & Cl_2	37,800	6.8	1,890	0.07	25,200	3.52	18,900	4.20
Leavenworth	S	Secondary (T.F.)	400	0.1	50	-	80	0.01	80	0.02
Cannelton	S	Primary & Cl_2	1,800	0.3	90	-	1,300	0.17	900	0.20
Tell City	C	Primary & Cl_2	6,600	1.2	330	0.01	4,400	0.61	3,300	0.73
Troy	S	Primary & Cl_2	500	0.1	25	-	330	0.05	250	0.05
Rockport	C	Primary & Cl_2	2,500	0.5	125	-	1,670	0.23	1,250	0.28
Newburgh	S	Primary & Cl_2	1,400	0.2	70	-	950	0.13	700	0.16
Indiana Total			78,600	14.2	3,955	0.14	52,210	7.28	39,180	8.71
Grand Total			555,200	100.0	2,912,040	100.0	717,350	100.0	449,780	100.0

Notes: (1) C - Combined Storm and Sanitary Sewers

S - Separate Storm and Sanitary Sewers

(2) Calculated from Survey Data Using:

1 Bacterial P.E. - (67 billion/capita/day) total coliforms

1 BOD P.E. - 0.167 lb/capita/da,

1 Suspended Solids P.E. - 0.2 lb/capita/day

WATER QUALITY

AESTHETICS

Webster's Unabridged Dictionary defines aesthetics as ". . . the theories of beauty, its essential character, the tests by which it may be recognized or judged, and its characteristic relation to or effect upon the human mind." The appearance of pollution and the fear of pollution detract from aesthetic values. The knowledge that water is clean enhances aesthetic appreciation.

The standards submitted by Indiana and Kentucky under the Federal Water Quality Act of 1965 stipulate requirements to maintain aesthetically pleasing waters. Among other things, these standards prohibit waste discharges that settle to form putrescent or otherwise objectionable deposits; that cause unsightly or deleterious amounts of floating debris, oil, scum and other floating materials; that produce color, odor or other conditions in such degree as to create a nuisance; and which are toxic or harmful to human, animal, plant or aquatic life.

The Louisville sewage treatment plant discharge is readily visible at normal pool stages. On calm days, an objectionable "sewage slick" can be seen for as far as one mile downstream along the Kentucky bank of the river. The typical "musty" odor of domestic sewage is also evident. Along the Kentucky shore, a sludge bank, partially composed of unremoved sewage particles, produces odors and reduces severely the River's aesthetic value.

Farther downstream, exposed industrial wastes and cooling water outfalls are located high on the banks. Wastes enter the river by flowing directly down the banks or in flumes. Foamy waste discharges created unsightly billows of foam on the river and accentuated the aesthetically unpleasing situation.

Unpleasant tastes and odors in fish taken from the Ohio River make the river less desirable for the recreational pursuit of fishing.

LATERAL MIXING

The low velocity in the Ohio River during the low flow periods and the resultant low turbulence level does not cause effective lateral mixing of waste discharges. This lack of lateral mixing makes the selection of sample points on a cross section difficult to properly locate. A theoretical analysis of lateral mixing was made downstream from Louisville (Appendix C). Limited field data which were collected in the Owensboro-Evansville reach in October, 1968 illustrated the effects from low lateral mixing rates (Appendix E).

The results obtained from the theoretical analysis and field observations confirmed that multiple point sampling is required.

In certain situations it is possible that the entire waste load might be missed by not sampling properly. The possibility of this situation has been demonstrated downstream from Owensboro (Appendix E). Sampling problems because of the lack of lateral mixing also undoubtedly occur in the Louisville reach.

Lateral mixing should occur as the river flow is forced through relatively small areas in passing the wicket dams. At low flow, most of the water would pass through the bear traps which causes turbulence and mixing.

FLOW

During low flows when the Ohio River is in pool condition, flow measurement is difficult because of the low water velocities that occur. Flow estimates are available from the U. S. Geological Survey, U. S. Army Corps of Engineers, and the U. S. Weather Bureau at various locations along the river. Louisville, Kentucky, and Evansville, Indiana, are two such locations.

Available flow estimates for McAlpine Dam during the survey period are presented in Appendix Table D-1. The flow used for Louisville was 46,200 cfs as determined by the Geological Survey.

The flow estimate used for Evansville was 50,780 cfs. This flow was determined from drainage area yield factors (Appendix Table D-2) and was checked, approximately, by calculations using the Geological Survey rating curve for this station.* Geological Survey flow data were used for the Green and Salt Rivers.

Table 3 shows the average flows during the October 2-13, 1967 survey period and the low 30-day flows with an average recurrence frequency of once in 10 years. Comparison of the survey period with the 30-day low flows** indicates that the study was not conducted during a drought period. Flows averaged 3 to 4 times the drought flows.

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*The rating curve is not within the accuracy standards of the Geological Survey at low flows. Five day average flows are published for this station in the water supply papers.

**Anon., "Hydrology of the Ohio River Basin," Appendix C, Ohio River Basin Comprehensive Survey, U. S. Army Corps of Engineers, Ohio River Division, Cincinnati, Ohio (August, 1966).

TABLE 3

SUMMARY OF OHIO RIVER FLOWS
October 2-13, 1967

RIVER	LOCATION	DRAINAGE AREA SQUARE MILES	OCTOBER 2-13, 1967 CFS	30-DAY 1 IN 10 YEARS LOW FLOW CFS
Ohio River	Louisville, Kentucky	91,170	46,200	13,000
Ohio River	Evansville, Indiana	107,000	50,790	16,000
Salt River	near Shepherdsville, Kentucky	1,197	14	-
Green River	near Calhoun, Kentucky	7,564	2,190	-

TEMPERATURE

Average water temperatures were 20° C at Louisville and 19° C at Evansville. These temperatures were lower than those that occurred during the mid-summer months of July and August, but were still representative of warm-weather conditions.

TIME OF WATER TRAVEL

Data for the Biochemical Oxygen Demand test and coliform bacteria have been graphed using time of water travel rather than river mile. This procedure illustrates data in a more orderly way than plotting concentration versus distance and shows the actual time associated relationships among the data. Both river mile location and time of travel downstream from the Louisville sewage treatment plant are given in the tables for BOD and coliform bacteria. The method used to calculate time of travel is present in Appendix D.

BIOCHEMICAL OXYGEN DEMAND (BOD)

Analyses Performed

Daily analyses for 2- and 5-day BOD's were made on samples from all 31 stations. This information was used to calculate the reaction rate and the ultimate first stage or carbonaceous BOD for each station.

Two sets of 20-day BOD's were run at selected stations to demonstrate the applicability of calculating the ultimate first stage BOD from the 2- and 5-day BOD data.
The 20-day BOD data were also used as a qualitative estimate of the second stage or nitrogenous BOD.

To evaluate the second stage or nitrogenous BOD, the total organic, ammonia, and nitrate forms of nitrogen were determined. It was postulated that the decrease in concentration of the total organic plus ammonia nitrogen would be equivalent to a decrease in the ultimate nitrogenous BOD when converted to an oxygen equivalent. * This postulation assumes that nitrogen fixation from the atmosphere and denitrification of oxidized nitrogen compounds is absent.

Results

The ultimate first and second stage BOD's of the river samples were calculated from the standard 2- and 5-day BOD and nitrogen data (Table 4, Figure 2).

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* McMichael, F. C. and J. E. McKee, "Wastewater Reclamation at Whittier Narrows," State of California Water Quality Control Board, Pub. No. 33, 1966.

Table 4

DISSOLVED OXYGEN & BIOCHEMICAL OXYGEN DEMAND

Ohio River: Louisville, Ky.-Evansville, Ind.

October 1967

Station		Time of Water Travel	Temp.	DISSOLVED OXYGEN		BIOCHEMICAL OXYGEN DEMAND								
						1st stage					2nd stage			
Designation	River Mile	Days	°C.	Avg. mg/1	Min. mg/1	2-day	5-day	Calc. k_1 per day	Graph. Extrap. k_1 per day	Ult. 1st stage mg/1	NH_3-N_2 mg/1	Org.-N_2 mg/1	NH_3+Org.-N_2 mg/1	Oxygen Equiv. mg/1
O-1	600.6		20.1	5.9	5.0	1.1	2.4	0.042	-	2.5	0.45	1.04	1.49	6.81
O-3	618.0	0.20	19.8	6.5(1)	5.4(1)	1.3(2)	2.0(2)	0.170	0.148	2.4	0.38	1.02	1.40	6.40
O-4	625.7	0.47	19.7	6.6(1)	5.2(1)	1.0(2)	1.6(2)	0.150	0.144	2.0	0.24	0.95	1.19	5.44
Salt River	629.9-0.2		19.7	4.7	4.2	1.3	2.1	0.170	-	2.5	0.51	1.00	1.51	6.90
O-5	633.5	0.77	19.9	7.2	6.2	1.0	1.7	0.134	0.138	2.1	0.32	0.92	1.24	5.67
O-6	645.7	1.16	19.8	7.3(1)	6.4(1)	0.8(2)	1.5(2)	0.111	0.132	1.9	0.28	0.84	1.12	5.12
O-7	650.8	1.33	19.7	7.1	6.0	1.0	1.8	0.106	0.129	2.3	0.21	0.80	1.01	4.62
O-8	665.5	1.82	19.6	7.7	7.0	0.9	1.7	0.110	0.121	2.3	0.26	0.92	1.18	5.39
O-9	667.3	1.94	19.5	7.4	6.7	1.0	1.7	0.148	0.119	2.3	0.22	0.96	1.18	5.39
O-10	678.2	2.36	19.6	7.4	6.6	0.9	1.5	0.136	0.113	2.1	0.18	0.84	1.02	4.66
O-11	682.9	2.55	19.6	7.3	6.3	0.8	1.4	0.145	0.111	1.9	0.25	0.83	1.08	4.94
O-12	689.8	2.85	19.5	7.2	6.2	0.8	1.5	0.104	0.107	2.1	0.26	0.78	1.04	4.75
O-13	700.9	3.32	19.4	7.2	6.5	0.9	1.5	0.140	0.100	2.2	0.24	0.82	1.06	4.84
O-14	705.6	3.66	19.3	7.0	6.5	0.6	1.1	0.090	0.096	1.6	0.27	0.71	0.98	4.48
O-15	710.5	3.72	19.2	7.3	6.1	0.6	1.1	0.100	0.096	1.6	0.29	0.76	1.05	4.80
O-16	717.2	3.99	19.2	7.4	6.3	0.5	1.0	0.040	0.092	1.5	0.24	0.67	0.91	4.16
O-17	723.5	4.25	19.2	7.3	6.6	0.6	1.1	0.070	0.089	1.7	0.24	0.72	0.96	4.39
O-18	726.4	4.38	19.2	7.2	6.6	0.4	0.9	0.070	0.088	1.4	0.26	0.79	1.05	4.80
O-19	730.0	4.52	19.2	7.3(1)	6.6(1)	0.5(2)	1.1	0.074	0.086	1.8	0.30	0.86	1.16	5.30
O-20	736.6	4.84	19.2	7.4	6.8	0.4	0.9	0.065	0.083	1.5	0.27	0.73	1.00	4.57
O-21	741.3	5.06	19.4	7.3	6.7	0.6	1.2	0.077	0.081	2.0	0.30	0.74	1.04	4.75
O-22	752.8	5.71	19.2	7.3(1)	6.7(1)	0.6(2)	1.2(2)	0.078	0.074	2.1	0.32	0.82	1.14	5.21
O-24	763.0	6.15	19.3	7.9(1)	7.5(1)	0.6(2)	1.2(2)	0.070	0.071	2.2	0.33	0.89	1.22	5.58
O-25	769.8	6.52	19.3	7.9	7.0	0.8	1.2	0.176	0.067	2.2	0.30	0.84	1.14	5.21
O-26	778.1	6.92	19.2	8.2	7.5	0.4	1.1	0.010	0.064	2.1	0.31	0.86	1.17	5.35
O-27	784.0	7.14	19.3	8.2	7.6	0.6	1.2	0.067	0.062	2.4	0.26	0.93	1.19	5.44
Green River	784.3-0.2		20.2	7.6	7.2	0.4	0.9	0.057	-	2.6	0.14	0.65	0.79	3.61
O-29	786.8	7.25	19.3	8.2(1)	7.6(1)	0.8(2)	1.6(2)	0.052	0.062	3.1	0.34	0.76	1.10	5.03
O-30	791.5	7.45	19.2	8.1	7.4	0.7	1.4	0.054	0.060	2.9	0.28	0.87	1.15	5.26

Notes:

(1) Average over cross-section from quarter point samples.

(2) Composite samples from quarter point samples.

30-a

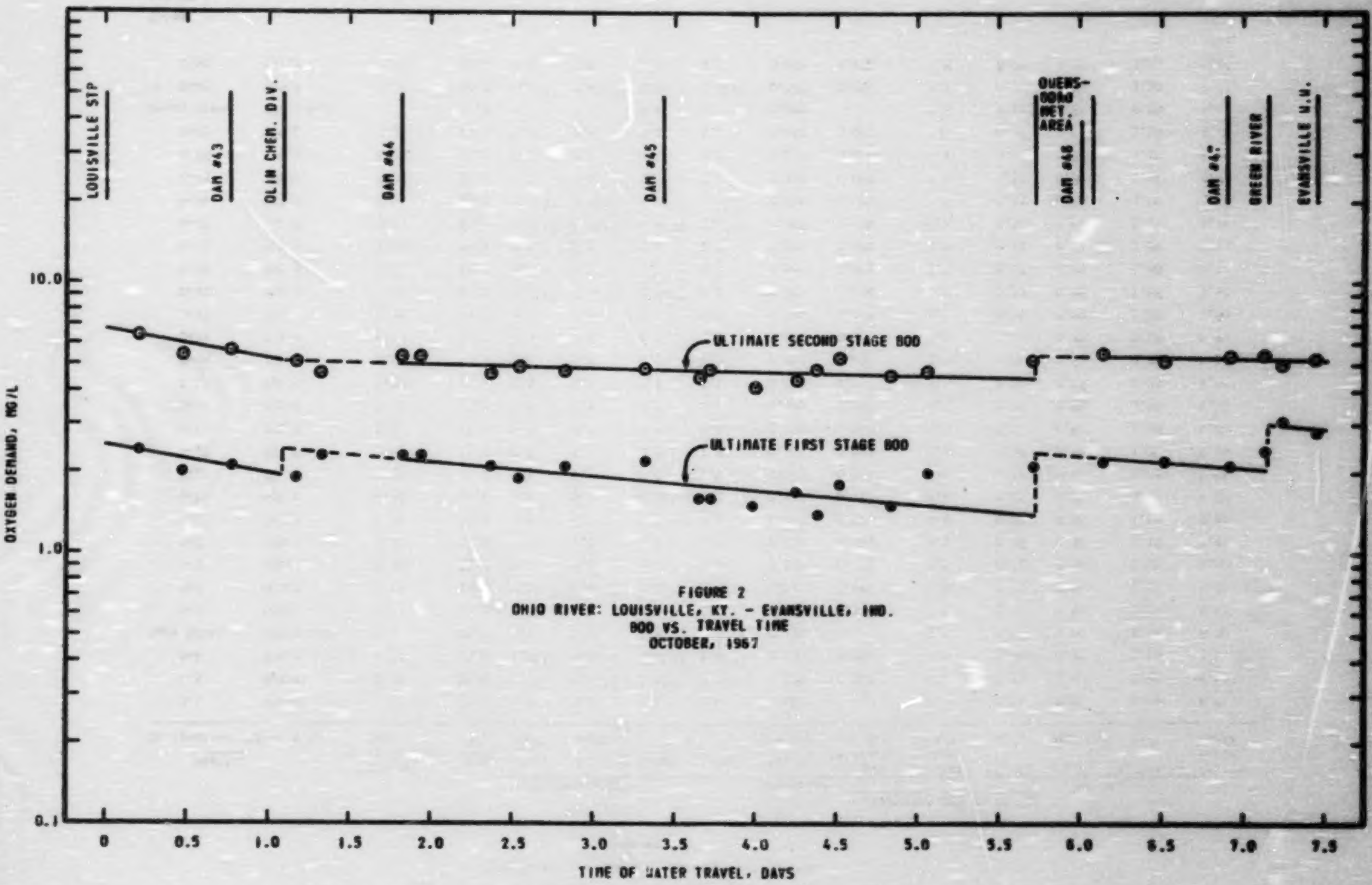

FIGURE 2
OHIO RIVER: LOUISVILLE, KY. - EVANSVILLE, IND.
BOD VS. TRAVEL TIME
OCTOBER, 1967

To obtain the ultimate first stage BOD, the oxidation rates (k_1) from the 2- and 5-day BOD results were calculated for each station. The individual rates were plotted against river time of travel (Figure 3). The indicated line was fitted by the method of least squares. From this graph, it was noted that the k_1 rates decreased in the downstream direction. The k_1 rates taken from this line were used to calculate the ultimate first stage BOD's for the various stations. The k_1 rates determined by this procedure varied from a maximum of 0.148 per day at Louisville to 0.060 per day at Evansville.

The profiles show the ultimate carbonaceous and ultimate nitrogenous BOD concentrations in the river (Figure 2). The total ultimate BOD is the sum of these two curves. Increases in BOD concentrations because of waste loads and tributary inflow are shown with broken lines or as sharp breaks in the curves where the loads enter the river. BOD loads are indicated for the Louisville, Kentucky-New Albany, Indiana, Metropolitan Area; the Olin Mathieson Chemicals Division Plant at Brandenburg, Kentucky; the Owensboro, Kentucky, Metropolitan Area; and the Green River.

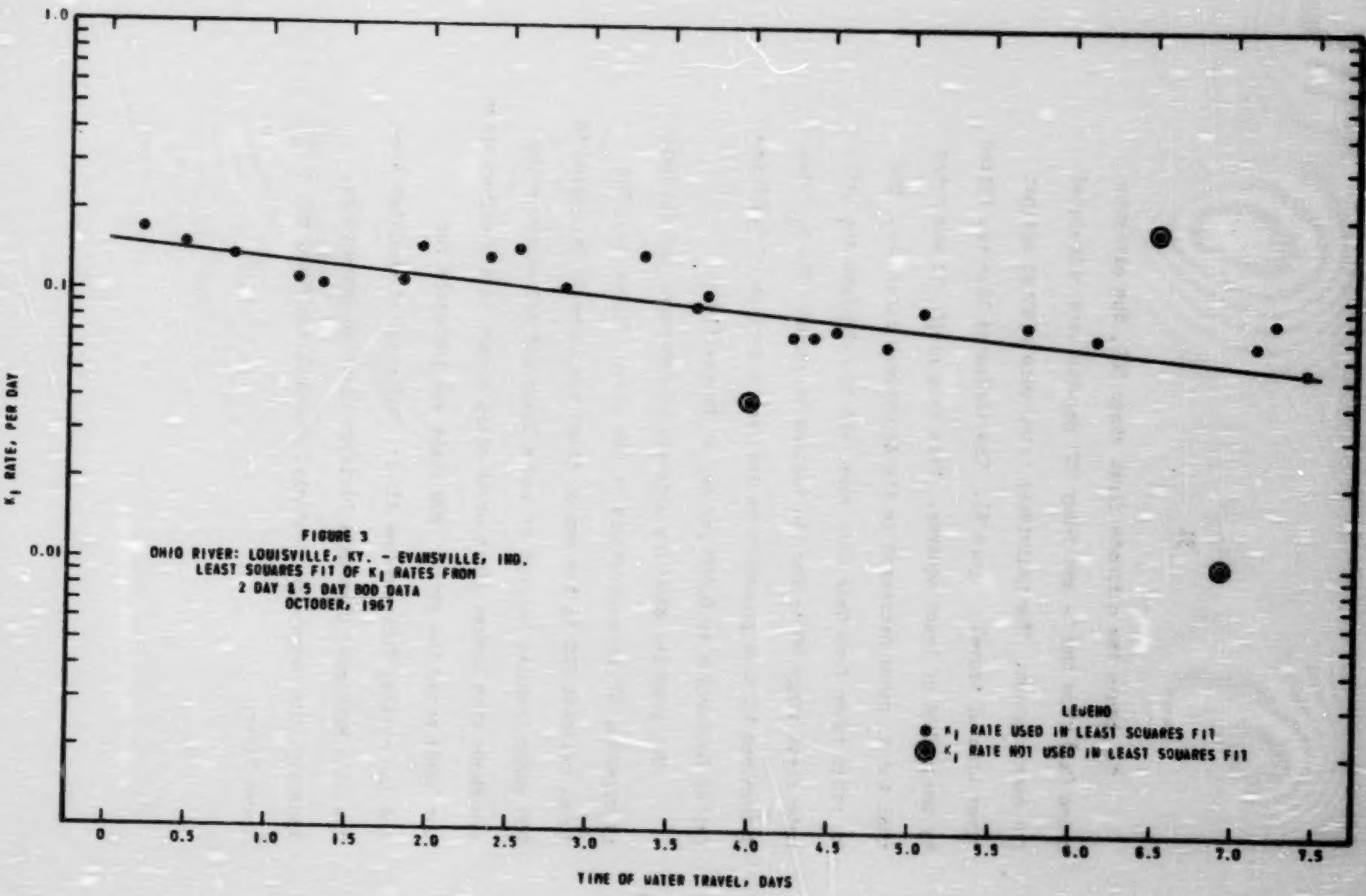

FIGURE 3
OHIO RIVER: LOUISVILLE, KY. - EVANSVILLE, IND.
LEAST SQUARES FIT OF K_1 RATES FROM
2 DAY & 5 DAY BOD DATA
OCTOBER, 1967

Average 5-day BOD's were low and ranged from 2.4 mg/l in McAlpine Pool to 0.9 mg/l 125 miles downstream at station 0-18. The concentration near the Evansville Water Works intake was 1.4 mg/l.

Tributary Streams

Salt River

The Salt River, which receives sewage discharges from the U. S. Army Post at Ft. Knox, Ky. and several subdivisions in the Louisville area, enters the Ohio River 17.9 miles downstream from the Louisville sewage treatment plant. The 5-day BOD near the mouth of the stream was 2.1 mg/l. This concentration was close to that found in the Ohio River and was probably affected by backwater from the Ohio River.

Green River

The 2- and 5-day BOD in the Green River indicated a low rate of oxygen demand satisfaction. The calculated k_1 rate of 0.037 per day is indicative of either toxicity or oxidation of complex compounds, either from natural or man-made sources. The increase in ultimate first-stage BOD in the Ohio River downstream from the confluence with the Green River (from 2.4 mg/l to 3.1 mg/l) possibly indicated toxicity which is removed by dilution in the Ohio River, or possibly the Green River furnished a critical nutrient deficient in the Ohio River allowing further oxidation to proceed.

DISSOLVED OXYGEN

The dissolved oxygen (DO) concentrations at all sample stations in the Ohio River during the October 1967 survey were greater than the Indiana and Kentucky standards of not less than 5.0 mg/1 for 16 hours in any 24-hour period and not less than 3.0 mg/1 at any time (Table 4, Figure 4). The lowest average DO of 5.9 mg/1 and the lowest minimum DO of 5.0 mg/1 for an entire cross section occurred at station O-1 upstream from McAlpine Dam near the Louisville Water Company municipal intake. The sluggish, deep waters lying behind McAlpine Dam have a low water velocity and consequently a lower rate of reaeration than the pools behind the low head wicket dams downstream. This fact combined with oxygen demands of residual BOD from upstream and from the bottom muds accounted for the lower DO's at this station.

Downstream from McAlpine Dam, comparison of the average DO concentrations at the Indiana quarter point with that at the Kentucky quarter point, showed the concentration on the Kentucky side to be 1.4 mg/1 less than that on the Indiana side at station O-3, 6 miles downstream from the Louisville sewage treatment plant, and 1.9 mg/1 less at station O-4, 13.7 miles downstream from the

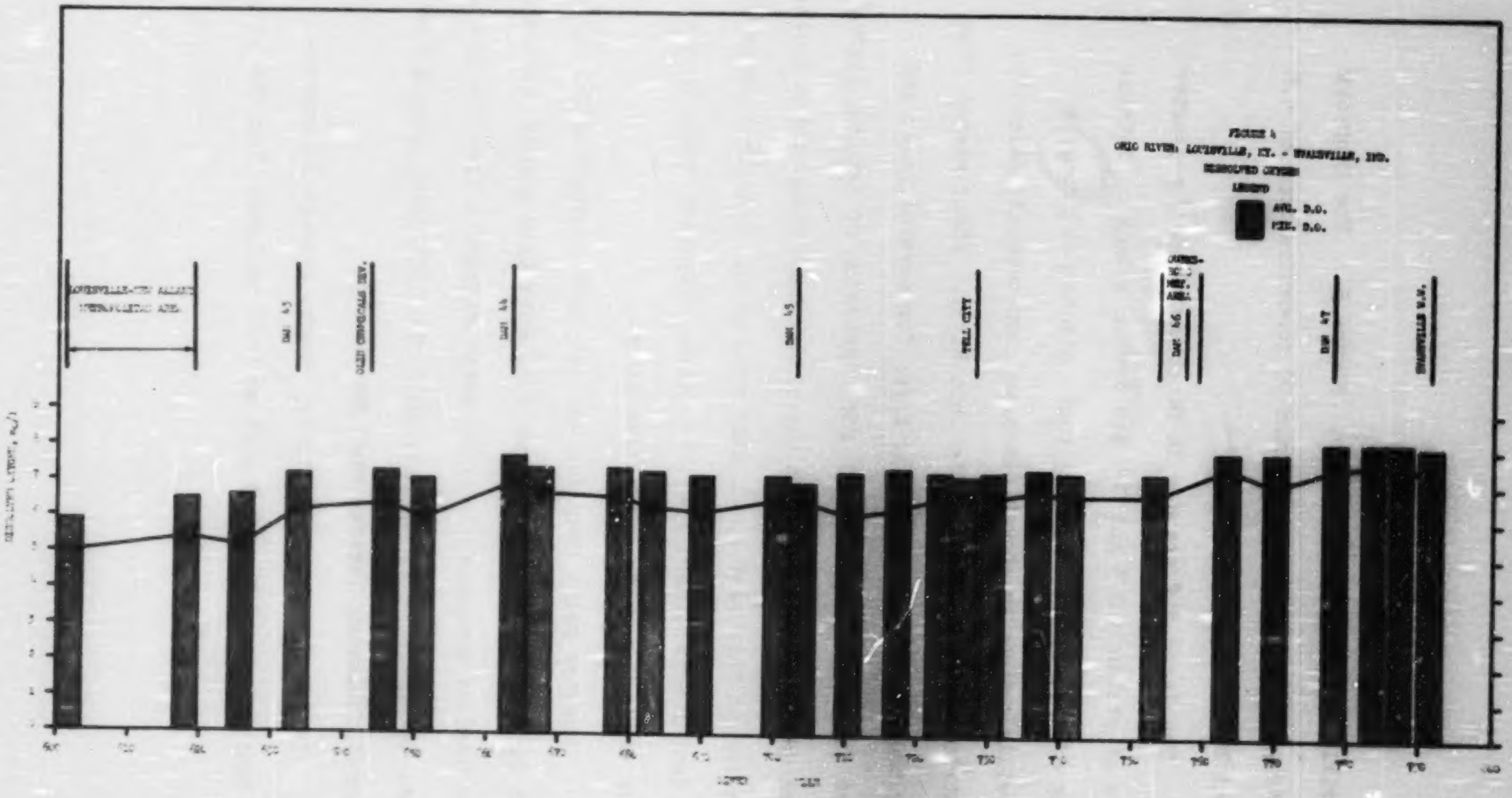

FIGURE 4
OHIO RIVER: LOUISVILLE, KY. - EVANSVILLE, IND.
DISSOLVED OXYGEN

Louisville sewage treatment plant (Figure 5). The Kentucky quarter point stations had minimum DO concentrations of 4.8 mg/l at both stations O-3 and O-4.

The large differences in DO observed at the quarter points at stations O-3 and O-4 are due to a lack of lateral mixing of the oxygen demanding waste discharges from the Louisville sewage treatment plant and non-sewered Louisville industries with the flow of the Ohio River. These wastes flow along the Kentucky shore of the river for several miles and reduce the DO (see Appendix C for discussion of lateral mixing). Oxygen demanding materials in the sludge bank along the Kentucky shoreline in this same reach also reduced the dissolved oxygen. This latter effect magnified the oxygen reduction owing to the oxygen demanding waste discharges alone.

Quarter point sampling was not used at station O-5 located 21.5 miles downstream from the Louisville sewage treatment plant because adequate mixing of waste effluents from the Louisville, Kentucky-New Albany area with the Ohio River should have occurred following passage over Dam No. 43.

In the Owensboro, Kentucky, reach, average DO concentrations increased from 7.3 mg/l at O-22 upstream from the city

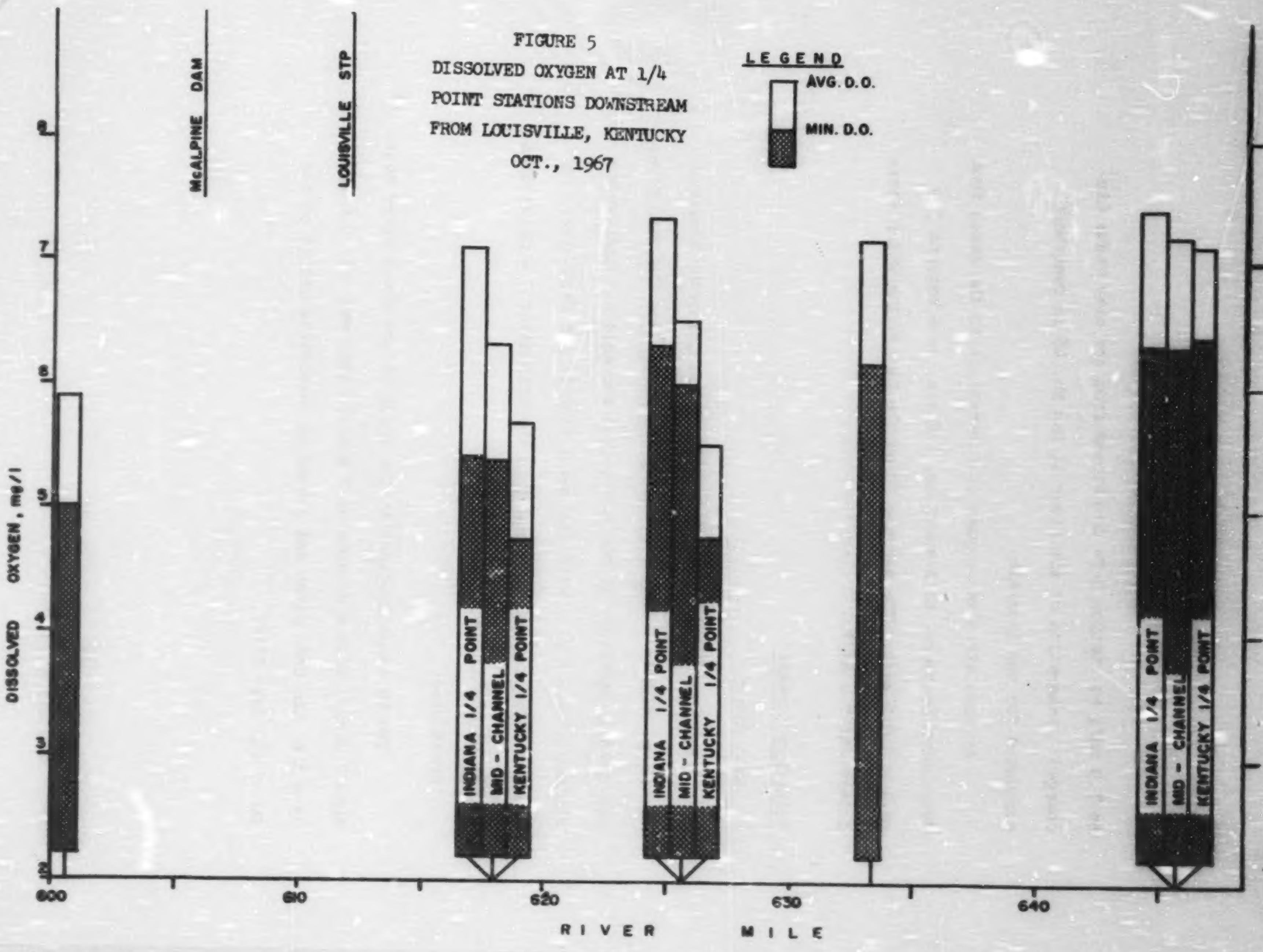

FIGURE 5
DISSOLVED OXYGEN AT 1/4
POINT STATIONS DOWNSTREAM
FROM LOUISVILLE, KENTUCKY
OCT., 1967

to 7.9 mg/l at station O-24 downstream from the city waste discharges. Reaeration of the river at Dam No. 46 in Owensboro accounted for the increase.

Average dissolved oxygen concentrations in the reach from Owensboro, Kentucky, to Evansville, Indiana, were between 7.9 mg/l and 8.2 mg/l. The average DO at the Evansville Water Works intake was 8.1 mg/l.

Tributary Streams

Salt River

The Salt River, receiving subdivision and other domestic wastes as well as being affected by backwater from the Ohio River, had DO concentrations at the mouth that averaged 4.7 mg/l with a minimum of 4.2 mg/l. With the small flow in the Salt River, no adverse effects on DO were noted in the Ohio River 3.4 miles downstream at station O-5.

Green River

The DO concentrations at the mouth of the Green River averaged 7.6 mg/l with a minimum of 7.2 mg/l; this was only 0.6 mg/l less than the Ohio River and caused no detectable effect on the DO of the Ohio River.

BACTERIAL POLLUTION

Sewage contains bacteria of the coliform group that typically occur in the fecal discharges of humans as well as all other warm-blooded animals. Bacterial results based on the entire coliform group (total coliforms) do have a disadvantage as an indicator of fecal pollution because several species of the group may come from sources other than sewage. To augment the total coliform test, a more specific test to identify and emmerate coliforms of fecal origin is used (fecal coliforms). This test measures coliform bacteria of fecal origin with a high degree of reliability.

Densities of both total and fecal coliforms are generally reported as the number per 100 milliliters of water (about 1/2 cup). Depending on the method of analysis used, coliforms are reported as a most probable number (MPN) for the multiple tube technique, or as an actual colony count for the membrane filter (MF) technique. The membrane filter technique was used for all coliform determinations during this study.

Recently, a technique for qualitatively insolating _Salmonella_ from water has been developed.* All _Salmonella_ are intestinal pathogens to man to some degree. This test is used to determine when a definite pathogenic bacterial group may be present in the waters. The source of Salmonella would be the fecal discharges of infected persons and other warm-blooded animals which enter the water primarily through sewage discharges.

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* Spino, D.F., "Elevated-Temperature Technique for the Isolation of _Salmonella_ from Streams," Appl. Microbiol., Vol. 14, 1966.

Observed Coliform Densities

The geometric means, the 80 percent confidence limits of the data, and the percentage of the coliform group that were specifically of fecal origin are listed in Table 5 and plotted in Figures 6, 7, and 8.

Station 0-1 located near the Louisville Water Company municipal water intake, was selected as a control station and to indicate bacteriological conditions upstream from Louisville in the lower pool areas behind McAlpine Dam. The station also indicated the bacteriological conditions in the raw water used by the city for the survey period. The geometric mean total coliform density at this station was 1,640 MF/100 ml. The fecal coliform density was 130 MF/100 ml or 7.9 percent of the total coliform density. The Indiana body contact recreation standard of 1,000 MF/100 ml total coliforms was violated at this station.

37-a

Table 5

COLIFORM BACTERIA

Geometric Mean & 80% Confidence Limits of the Data

Ohio River: Louisville, Ky.-Evansville, Ind.

Station	River	Time of	TOTAL COLIFORMS			MF/100 ml	FECAL COLIFORMS			MF/100 ml	Fecal Coliform
Designation	Mile	Water Travel Days	Mean	10% greater than	10% less than	Arithmetic Average	Mean	10% greater than	10% less than	Arithmetic Average	as a percent of Total Coliforms
0-1	600.6		1,640	2,760	980	1,770	130	250	72	140	7.9
Louisville STP (0-2)	612.0	0	63,700,000	129,000,000	39,500,000	67,875,000	11,100,000	29,700,000	4,160,000	13,742,000	17.4
0-3	618.0	0.20	740,000[1]	2,840,000	193,000	1,114,000	89,000[1]	417,000	19,000	146,200	12.0
0-4	625.7	0.47	396,000[1]	2,205,000	71,100	677,000	39,000[1]	321,000	4,760	86,400	9.8
Salt River 0-4A	629.9-0.2		1,640,000	3,840,000	704,000	1,954,000	112,000	275,000	46,400	138,800	6.8
0-5	633.5	0.77	486,000	2,840,000	83,300	853,000	53,800	250,000	11,600	89,900	11.1
0-6	645.7	1.16	343,000[1]	1,010,000	116,500	440,900	33,100[1]	81,500	13,400	47,100	9.6
0-7	650.8	1.33	429,500	802,000	230,000	481,200	42,400	81,200	22,200	47,800	9.9
0-8	663.5	1.82	246,000	591,000	102,000	293,700	25,000	95,200	6,550	43,200	10.2
0-9	667.3	1.94	241,000	509,000	114,500	281,000	21,400	44,100	10,400	24,900	8.9
0-10	678.2	2.36	72,300	180,000	29,000	90,500	8,490	24,600	2,920	11,100	11.7
0-11	682.9	2.55	76,200	238,000	24,400	104,900	7,940	26,600	2,370	11,500	10.4
0-12	689.8	2.83	71,500	184,000	27,800	91,500	6,960	23,900	2,020	10,300	9.7
0-13	700.9	3.32	35,400	101,000	12,400	45,400	3,240	12,300	860	5,000	9.2
0-14	703.6	3.66	52,000	131,000	20,600	64,600	3,390	11,300	1,010	4,890	6.5
0-15	710.5	3.72	41,400	92,300	18,500	49,000	2,540	7,160	900	3,300	6.1
0-16	717.2	3.99	38,150	99,300	14,650	46,400	2,540	7,640	850	3,370	6.6
0-17	723.5	4.25	21,600	76,600	6,090	30,600	1,720	3,860	760	1,970	8.0
0-18	726.4	4.38	28,500	65,500	12,400	33,500	1,750	3,690	830	2,010	6.1
0-19	730.0	4.52	24,900[1]	54,800	11,400	29,900	1,450[1]	2,700	780	1,590	5.8
0-20	736.6	4.84	26,400	54,700	12,700	30,300	1,660	3,120	880	1,850	6.3
0-21	741.3	5.06	22,200	46,500	10,600	25,250	1,460	2,840	750	1,570	6.6
0-22	752.8	5.71	15,600[1]	74,650	3,250	24,400	700[1]	1,610	310	800	4.5
Owensboro STP (0-23)	758.3	6.08	70,100,000	169,000,000	29,100,000	83,200,000	3,930,000	9,870,000	1,570,000	4,750,000	5.6
0-24	763.0	6.15	19,400[1]	57,300	6,550	26,500	940[1]	2,540	340	1,160	4.8
0-25	769.8	6.52	15,300	63,300	3,680	23,800	770	2,200	270	1,010	5.0
0-26	778.1	6.92	28,700	89,200	9,210	39,200	1,320	3,510	490	1,690	4.6
0-27	784.0	7.14	33,900	106,000	10,900	47,900	1,230	2,110	720	1,310	3.6
Green River (0-28)	784.3-0.2		520	3,180	86	1,010	18	[illegible]	8	21	3.5
0-29	786.8	7.25	32,600[1]	139,000	7,690	55,670	940[1]	2,010	440	1,100	2.9
0-30	791.5	7.45	27,700	91,300	8,420	30,840	1,010	2,350	440	1,230	3.6

Note: [1] Composite sample from quarter point samples.

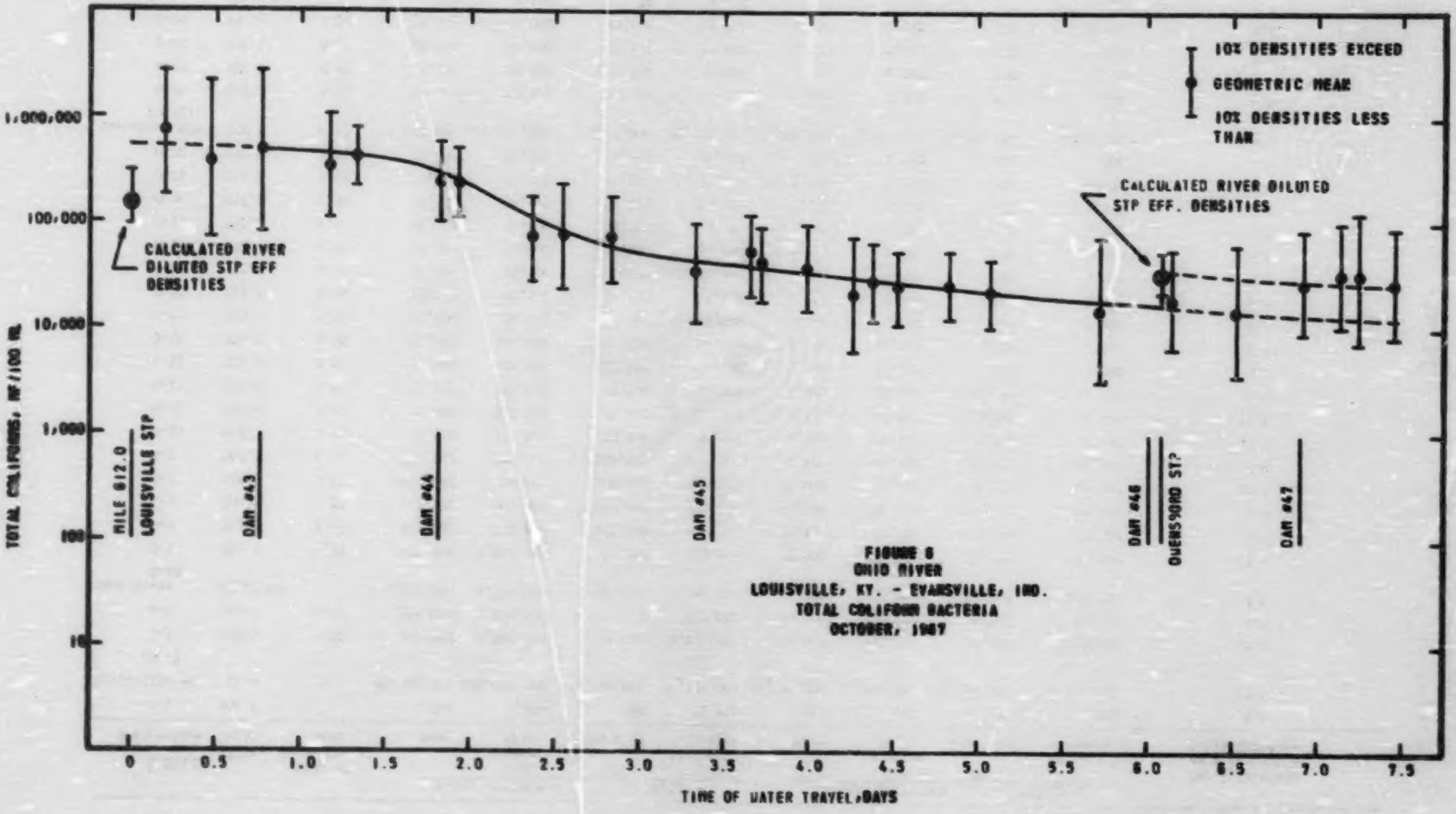

FIGURE 8
OHIO RIVER
LOUISVILLE, KY. - EVANSVILLE, IND.
TOTAL COLIFORM BACTERIA
OCTOBER, 1967

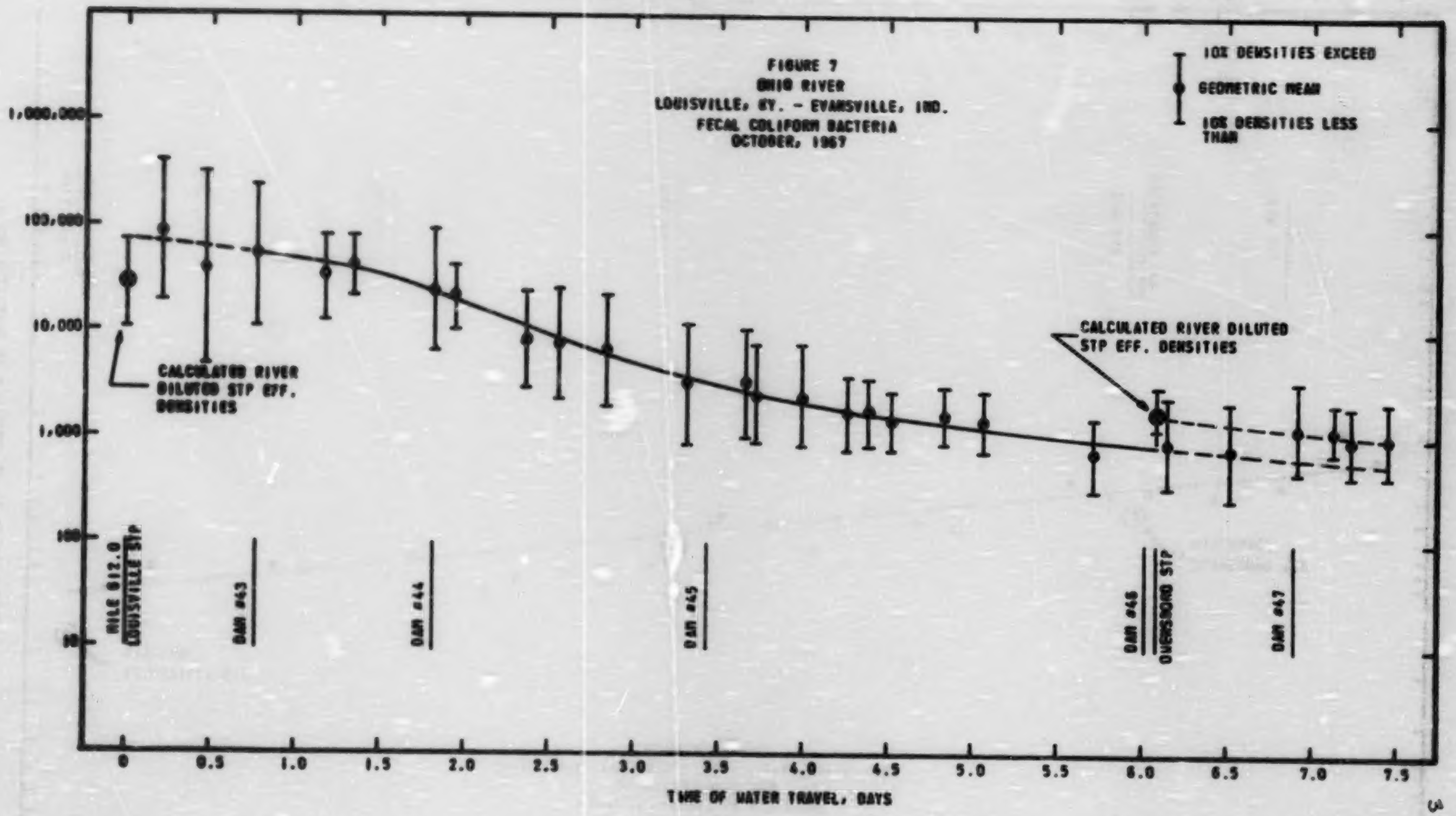

FIGURE 7
OHIO RIVER
LOUISVILLE, KY. - EVANSVILLE, IND.
FECAL COLIFORM BACTERIA
OCTOBER, 1967

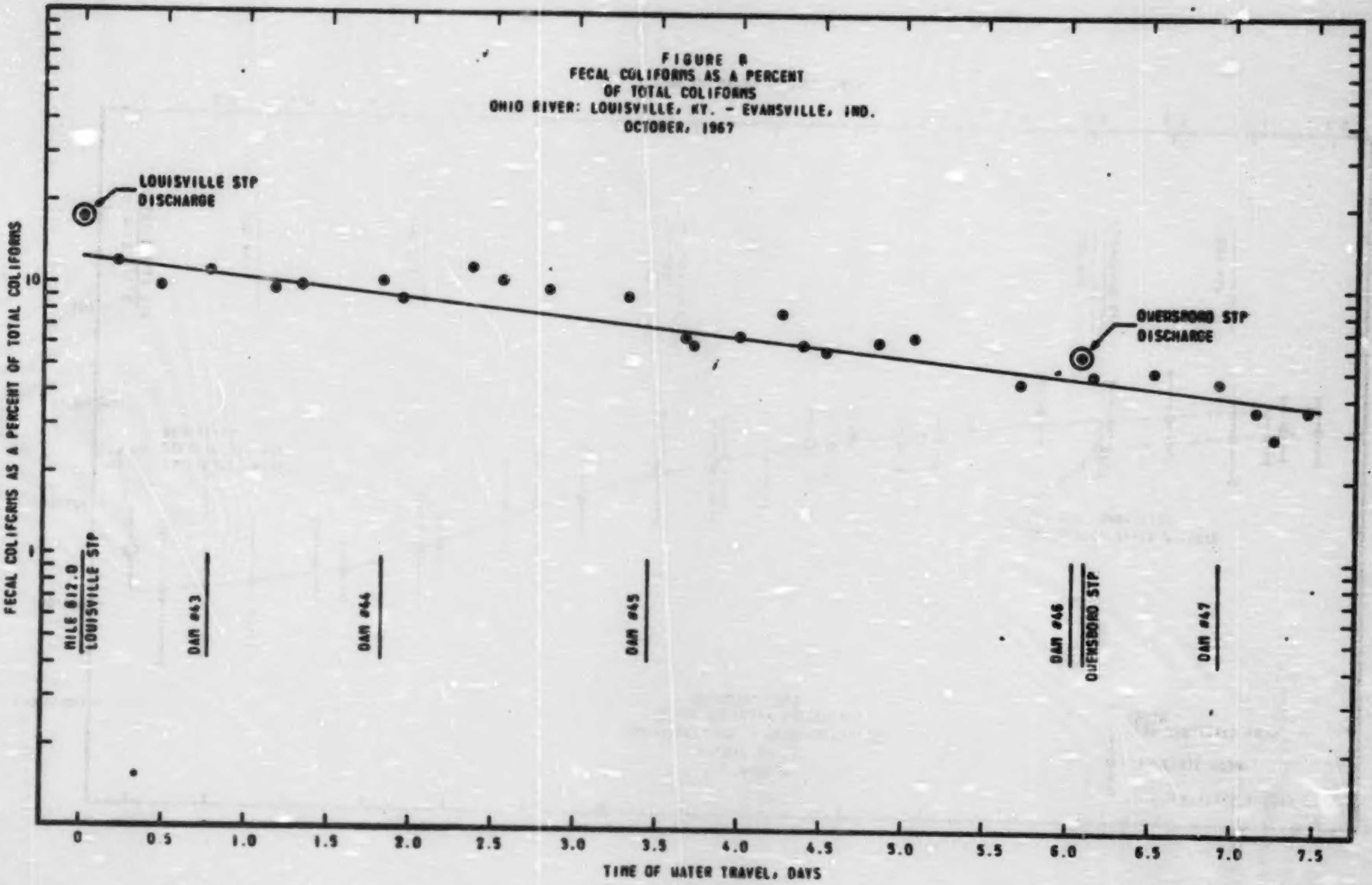

FIGURE 8
FECAL COLIFORMS AS A PERCENT
OF TOTAL COLIFORMS
OHIO RIVER: LOUISVILLE, KY. - EVANSVILLE, IND.
OCTOBER, 1967

Downstream from McAlpine Dam the treated sewage discharges from Jeffersonville, Clarksville and New Albany, Indiana, and from Louisville, Kentucky enter the Ohio River. In the Louisville sewage treatment plant discharge (Station 0-2), the geometric mean densities were 63,700,000 per 100 ml total coliforms with 17.4 percent or 11,100,000 per 100 ml fecal coliforms.

The highest mean densities measured downstream from the Louisville area occurred at station 0-3, 0.2 day travel time downstream. Densities were 740,000 per 100 ml total coliforms and 89,000 per 100 ml fecal coliforms.

Continuing downstream from the Louisville metropolitan area, total and fecal coliform densities exhibited a generally decreasing pattern (Figures 6 and 7). The percentage of fecal coliforms also decreased (Figure 8). Several small communities discharged treated and untreated wastes between Louisville and Owensboro, Kentucky, but their effects were masked by the high residual coliform densities from the Louisville metropolitan area, the variation in density in the river, and the high dilution afforded by river flows in excess of 46,000 cfs.

At station 0-22 located upstream from Owensboro, Kentucky, but 140.8 miles and 5.7 days travel time downstream from the

Louisville sewage treatment plant, the geometric mean total coliform density had decreased to 15,600 MF/100 ml. Fecal coliforms were 4.5 percent of the total coliforms and had a geometric mean of 700 MF/100 ml. Even at this great distance downstream from Louisville, the total coliforms exceeded the 1,000 MF/100 ml Indiana bacteriological standard for body contact sports by 15.6 times and the 5,000 MF/100 ml Indiana and Kentucky general recreation standard and public water supply standard by 3 times.

The coliform density pattern downstream from the Owensboro sewage treatment plant discharge was not fully defined during the October, 1967 survey. The effect from this effluent was not detected until the river passed over Dam 47.

The results from a survey in October, 1968 showed the poor lateral mixing downstream from Owensboro and indicated the total and fecal coliform pattern (Appendix E).

The geometric mean total and fecal coliform densities for the October, 1967 survey were 27,700 MF/100 ml and 1,010 MF/100 ml respectively, at station 0-30 near the Evansville Water Works Intake. This station was 1.4 days travel time downstream from Owensboro and approximately 7.5 days travel time downstream from Louisville.

Calculations for total coliforms (based on Figure 6) for station O-30 indicate that of the total coliform density of 27,700 MF/100 ml, about 13,500 MF/100 ml or 48.7 percent was from sources upstream from Owensboro and primarily from the Louisville area; and about 14,200 MF/100 ml or 51.3 percent was from the Owensboro area. Calculations for fecal coliforms indicated a similar distribution.

The total coliform densities at station O-30 violated the 5,000 MF/100 ml Indiana and Kentucky standards for domestic water supply sources and for general recreation by 5.5 times. The 1,000 MF/100 ml Indiana body contact recreation standard was violated by 27.7 times.

Tributary Streams

Salt River

The Salt River contained extremely high total and fecal coliform densities. The geometric mean total coliform density was 1,640,000 MF/100 ml; fecal coliforms were 6.8 percent of the total coliforms and had a geometric mean density of 112,000 MF/100 ml. The principal sources of these coliforms were sewage discharges from housing subdivisions and backwater from the Ohio River. The effects of these high coliform densities were not noted in the Ohio River because of the low flow in the Salt River compared to that of the Ohio River.

Green River

Total and fecal coliform densities observed in the Green River were relatively low. The geo metric mean total coliform density was 520 MF/100 ml; fecal coliforms were 3.5 percent of the total coliforms and had a geometric mean of 18 MF/100 ml. No adverse effect on the bacteriological quality of the Ohio River was observed downstream from the confluence with the Green River.

Salmonella Isolation

To determine the presence or absence of pathogenic bacteria in the Ohio River, gauze "swabs" were placed at selected stations for a period of five days to isolate *Salmonella*, an intestinal pathogenic group of bacteria. Five stations were selected to represent bacteriological conditions for a 33.7 river mile reach downstream from the sewage discharges in the Louisville, Kentucky-New Albany, Indiana, area.

In the Owensboro, Kentucky, to Evansville, Indiana, river reach, five stations were also selected.

Pathogenic Salmonella were isolated at 9 out of 10 stations tested confirming the presence of pathogenic bacteria.

OTHER CONSTITUENTS AND DETERMINATIONS

pH

The average pH's varied from 7.3 units at Louisville to 7.6 units at Evansville. This level indicates slightly alkaline conditions, and is well within the limits of pH 5 - pH 9 for aquatic life as specified by the proposed Kentucky standards and the limits of pH 6 - pH 9 of Indiana. The Green and Salt Rivers were also slightly alkaline, with pH's of 7.4 units and 7.8 units, respectively.

Specific Conductance

The Indiana and Kentucky public water supply standards for dissolved solids are a maximum of 500 mg/l for a monthly average, and not more than 750 mg/l at any time. The standards note that these requirements are met by specific conductances of 800 and 1,200 micromhos per centimeter (µmho/cm), respectively.

Average specific conductances ranged between 520 µmho/cm at Louisville to 550 µmho/cm at Evansville. These levels were less than the respective states' standards. The Salt and Green Rivers had average specific conductances of 530 µmho/cm and 430 µmho/cm respectively.

Turbidity

Average turbidity levels ranged from 13 Jackson Candle Units (JCU) at Louisville in McAlpine Dam Pool to 38 JCU at Evansville. The Salt and Green Rivers likewise had low turbidities averaging 15 JCU and 34 JCU, respectively.

Suspended Solids

Average total suspended solids concentrations ranged from 11 mg/1, downstream from Louisville, to a high of 34 mg/1 at station O-7, downstream from the Olin Mathieson Chemicals Division Plant at Brandenburg, Kentucky. In the vicinity of the Evansville Water Works, the total suspended solids averaged 29 mg/1.

Volatile solids made up 25 to 33 percent of the total suspended solids, which is indicative of significant organic content in the suspended solids. The organic fraction would include fecal particles contained in sewage, organic sludges from industrial operations, plankton, and natural organics from land drainage (leaf fragments, etc.). The inorganic fraction would consist of silty materials from land drainage or bottom muds stirred by gravel and dredging operations.

Final effluents from the Louisville and Owensboro, Kentucky, sewage treatment plants which provide primary treatment, contained average total suspended solids concentrations of 122 mg/l and 99 mg/l, respectively. Volatile solids were 61 and 85 percent of the total suspended solids. These concentrations were higher than the 15-20 mg/l total suspended solids usually found in effluents from plants providing secondary treatment.

STREAM BED ORGANISMS AND PLANKTON

The density and kinds of bottom-associated organisms delineate the areas that were polluted by waste discharges, and the extent to which the biological community has been altered. Bottom organisms, because they lack extensive mobility, are subjected to all environmental changes, and they react to these changes with population changes in the bottom organism community.

This biological study of the Louisville reach included a review of data from stations that were sampled in 1914 and 1915. The 1914 and 1915 results were expressed as numbers of organisms per 200 ml of sediment sample. In these years, the area upstream from Louisville (RM 600. 0-1) had an average of 12 pollution-tolerant sludgeworms, 8 intermediately tolerant and 0 intolerant organisms per 200 ml of sediment; in 1967, this same area supported 4 pollution-tolerant sludgeworms, 2 intermediately tolerant midges and 1 Asiatic clam, and 0 intolerant organisms per 200 ml of sediment. Though slightly fewer organisms were present in 1967, the satisfactory water quality has remained relatively unchanged.

Sediment samples upstream from Louisville contained 0.16 percent organic nitrogen and 3.50 percent organic carbon, indicating stabilized organic materials. The dissolved oxygen content of the overlying waters in this reach was decreased by the oxygen consumption of the sludge at a rate of 0.75 grams oxygen per day per square meter (gm O_2/day/m^2). Because of the slack water created by McAlpine Dam at Louisville, there was only a small amount of dissolved oxygen added through reaeration.

Pollution abatement has not kept pace with the expansion of Louisville, Kentucky, and New Albany, Indiana. In 1914-1915 the station downstream from these pollutional sources supported 20 pollution-tolerant organisms and 25 other organisms per 200 ml of sediment; in 1967, only pollution-tolerant sludgeworms numbering 16 per 200 ml were found, indicating that only the more pollution-tolerant organisms now survive 6 miles downstream from the waste sources.

Evidence of pollution downstream from Louisville and New Albany is further indicated in Figure 9 by the decreased number of kinds of organisms, from 8 upstream to 3 downstream from these sources, and the increased number of tolerant sludgeworms from 38 to 76 per square foot downstream at RM 625.7 (0-4). The "line of degradation" in Figure 9 depicts where the number of kinds was

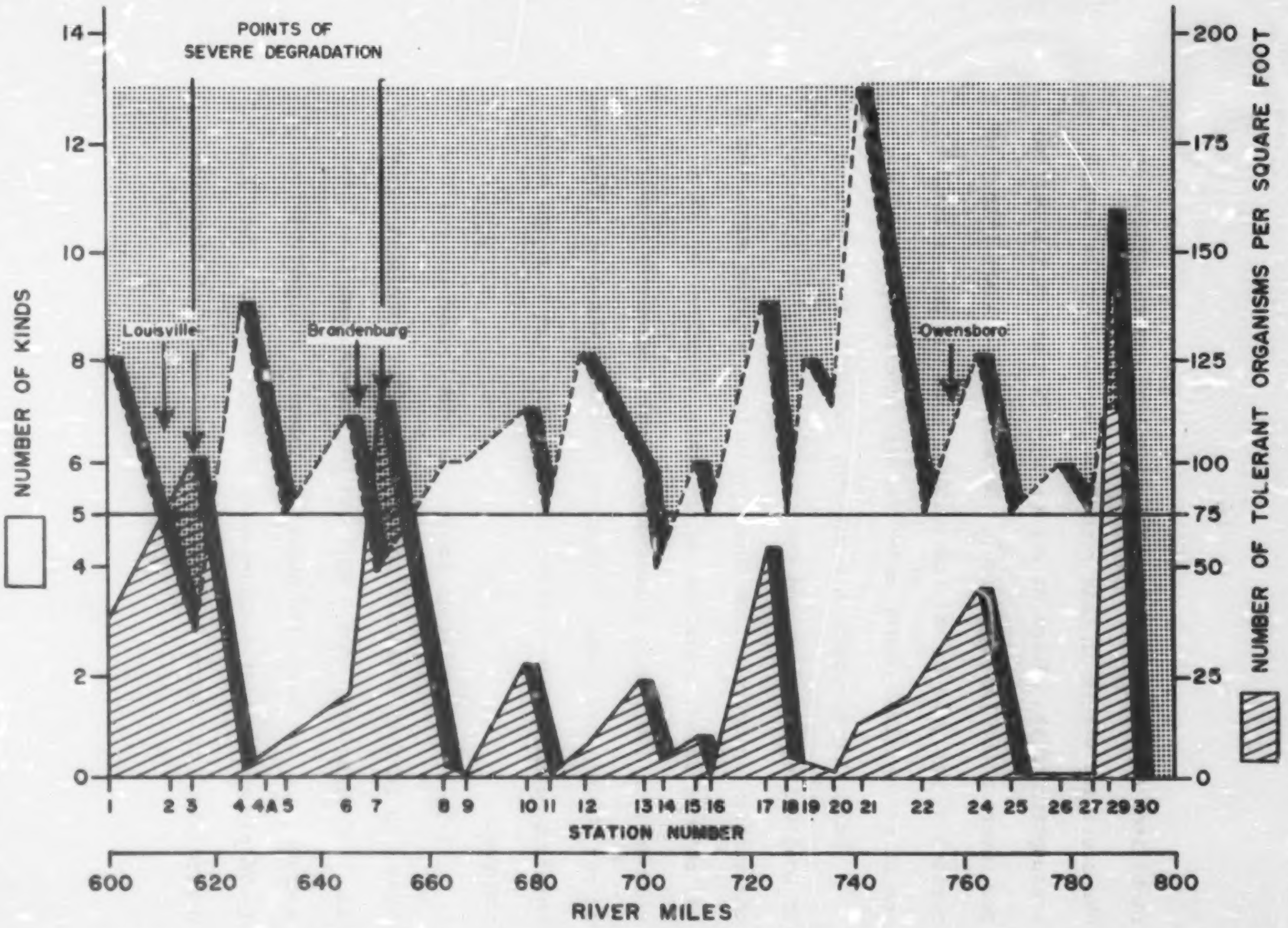

FIGURE 9 AREAS OF BOTTOM ORGANISM DEGRADATION IN THE OHIO RIVER BETWEEN LOUISVILLE, KY. AND EVANSVILLE, IND., OCTOBER 1967.

reduced to less than 5 and the number of pollution-tolerant organisms was increased to 75 or greater per square foot. When either the number of pollution-tolerant organisms is greater, or the number of kinds is less than this "line of degradation," organic pollution is moderate. When both the number of pollution-tolerant organisms is greater than, and the number of kinds is less than, the demarcation line, organic pollution is severe. Organic pollution may be extremely severe when the number of tolerant organisms is less than the demarcation line. This could occur when the organic wastes are of sufficient strength to remove all the dissolved oxygen; in the table this would be "heavy."

No. of Tolerant Organisms Exceeds the Line		No. of Kinds Drops Below the Line		Indicated Organic Wastes
Yes	No	Yes	No	
x			x	Light Load
x		x		Medium Load
x ⟷	x	x		Heavy Load
				Toxic Wastes
	x		x	Light
	x	x		Heavy

These values are empirical for the Ohio River and were obtained by measuring the population of bottom animals in relatively unpolluted areas upstream from Louisville and Owensboro, Kentucky, versus values from polluted areas downstream from Louisville and Brandenburg, Kentucky.

Deposition of sludges along the Kentucky shore extended for 7.5 miles downstream from the Louisville sewage treatment plant. The sludge bank averaged 100 feet wide with an average depth of 6 inches (maximum depth, 15 inches). Upstream from the sewage treatment plant, oxygen demand rates were 0.7 compared to 6.1 gm $O_2/day/m^2$ 0.5 miles downstream from the plant within the confines of the sludge deposit. At RM 615 (2.5 miles downstream from the plant), the rate had decreased to 5.3 and at RM 618 the rate was 3.0 gm $O_2/day/m^2$ (Figure 10). Based on an integrated rate, the total oxygen consumption for the entire sludge bank was 4,267,600 gm O_2 per day (9,400 pounds). Downstream from McAlpine Dam at Louisville, swift currents restricted the deposition of sludge to the Kentucky shore. The sludge at RM 618 (0-3) was 0.28 percent organic nitrogen, 5.1 percent organic carbon, and 0.15 percent total phosphorus indicating that the sewage solids in this sludge had been only partially

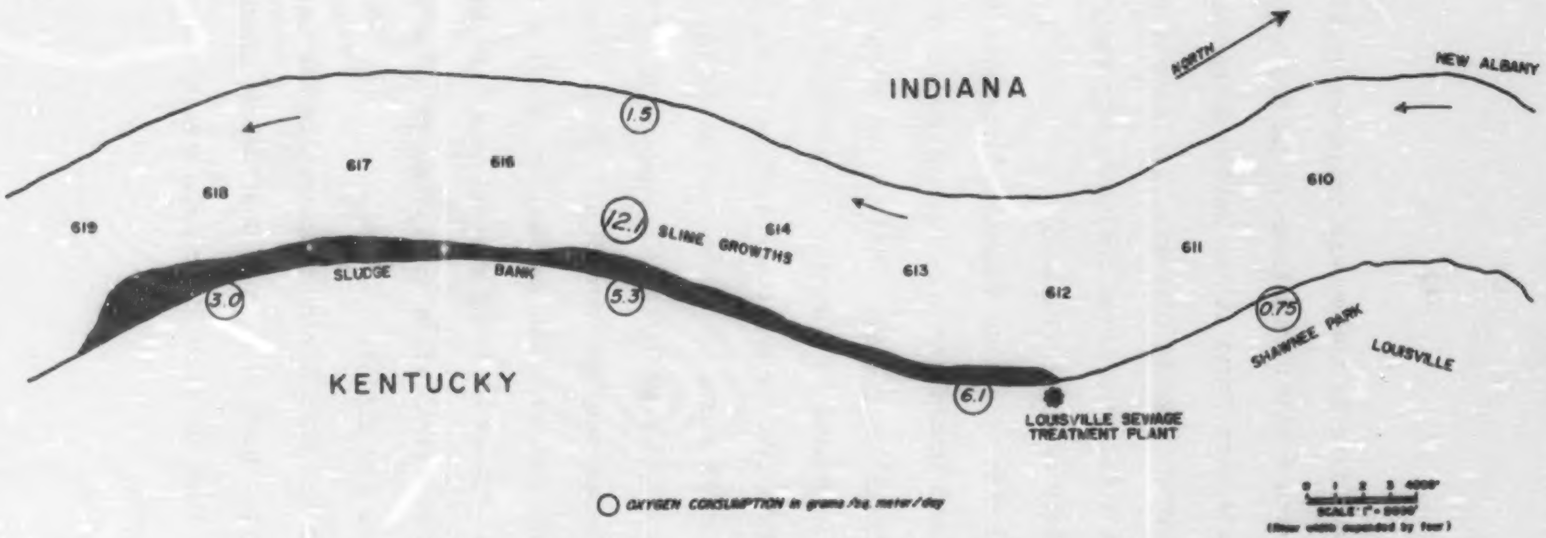
INDIANA
NORTH
NEW ALBANY
1.5
617
616
610
618
619
12.1
SLINE GROWTHS
614
611
613
612
SLUDGE
BANK
3.0
5.3
0.75
SHAWNEE PARK
LOUISVILLE
KENTUCKY
6.1
LOUISVILLE SEWAGE
TREATMENT PLANT
○ OXYGEN CONSUMPTION in grams/sq. meter/day
0 1 2 3 4000'
SCALE 1" = 8000'
(River width expanded by four)

FIGURE 10 SLUDGE DEPOSITS AND OXYGEN CONSUMPTION BY THESE DEPOSITS IN THE OHIO RIVER DOWNSTREAM OF LOUISVILLE, KENTUCKY, OCTOBER 1967.

oxidized and stabilized by the sewage treatment facilities. No sludge was observed 6 miles downstream at RM 625.7 (O-4); however, petroleum products were found in the bottom sediments. The low value of 0.09 percent organic nitrogen, 1.3 percent organic carbon, and 0.08 percent total phosphorus indicates the bottom materials had been completely oxidized (Table 6).

Another adverse condition caused by nutrients in wastes discharged from the Louisville area was the growth of slimes, principally Sphaerotilus natans. These slime growths restrict many stream bed organisms by covering their habitat and gills; slimes also lower the dissolved oxygen concentration in the overlying water. Slimes covering rocks south of mid-channel at RM 615 had an oxygen consumption rate of 12.1 gm O_2/day/m^2. Sphaerotilus natans was also found in the plankton samples from RM 618 (O-3). The slimes were heaviest along the Kentucky bank downstream from the Louisville sewage treatment plant. Chunks of "foam rubber" were observed floating on the Ohio River for several miles downstream from the American Synthetic Rubber Corporation (RM 613.6).

Plankton in the Ohio River at Louisville has been studied intermittently during the past 50 years. Conclusions drawn from these surveys indicate that the Ohio River possesses a plankton population

49-a

TABLE 6

Chemical Composition of
Bottom Sediments, Ohio River
(Louisville, Ky., to Evansville, Ind.)

Station Number	Percent Phosphorus	Percent Organic Nitrogen	Percent Carbon
0-1	0.11	0.16	3.5
0-2	-	-	-
0-3	0.15	0.28	5.1
0-4	0.08	0.09	1.3
0-4A	0.11	0.21	1.5
0-5	0.08	0.10	1.2
0-6	0.03	0.09	2.1
0-7	0.09	0.19	3.3
0-8	-	-	-
0-9	0.07	0.19	2.9
0-10	0.07	0.15	3.8
0-11	-	-	-
0-12	0.07	0.09	1.9
0-13	0.04	0.21	2.9
0-14	-	-	-
0-15	-	-	-
0-16	0.02	0.12	2.7
0-17	0.08	0.20	3.2
0-18	-	-	-
0-19	0.07	0.13	2.8
0-20	-	-	-

TABLE 6 Continued

Station Number	Percent Phosphorus	Percent Organic Nitrogen	Percent Carbon
0-21	0.08	0.15	1.8
0-22	-	-	-
0-23	-	-	-
0-24	0.08	0.14	3.2
0-25	0.03	0.01	0.6
0-26	0.03	0.09	3.3
0-27	0.02	0.04	1.4
0-28	0.02	0.00	< 0.3
0-29	0.04	0.13	1.5
0-30	0.02	0.00	< 0.3

different from that of its tributaries. An outstanding characteristic of the Ohio River plankton was the presence of genera not prominent in the plankton of its tributaries. It was also concluded that stable flows in the fall permitted heavy plankton production, including the fall "pulse" of diatoms. The numbers and concentrations of plankters has remained relatively constant during the last 50 years. The slight decrease in 1967 was probably caused by natural fluctuations. The following summary lists available data in comparable units.

Vol. and Counts of Algal Populations

Year	RM 598 (St. 0-1) Vol. (ppm)	RM 598 (St. 0-1) Total Count (No. per ml)	RM 619 (St. 0-3) Vol. (ppm)	RM 619 (St. 0-3) Total Count (No. per ml)
Sept.-Oct. '14	2.36	-	1.48	-
Aug.-Oct. '39	-	1,228	-	2,107
Oct. '67	0.45	900	0.2	650

The plankton concentration in the Ohio River has remained relatively low, thus minimizing this probable cause of taste and odor problems in water supplies. Low plankton concentrations have been observed for 50 years which predates much of the industrial development. In Table 8 of "Aquatic Life Resources of the Ohio River"* a listing of the tastes and odors of Ohio River water at Louisville, Kentucky, is presented for the period of October through December 1958 (as reported by the Louisville Water Company). This table lists the number of days that reported algal associated tastes and odors occurred along with the relative abundance of plankton. A summary from this table follows:

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* Anon. 1962. Aquatic Life Resources of the Ohio River. Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio. 218 pp.

1. During October, algal associated odors were present 61 percent of the days with abundant diatoms, green algae and blue-green algae.
2. During November, algal associated odors were present 93 percent of days with abundant diatoms and green algae.
3. During December, algal associated odors were present 29 percent of the days with diatoms and green algae being scarce.

This summary reveals a strong relationship between water supply odors and the relative abundance of algae. The percentage of days when algal associated odors were present in the Louisville water supply decreased when algal abundance decreased.

The Analytical Quality Control Laboratory, Federal Water Pollution Control Administration, examined 20 plankton samples collected at Louisville, Kentucky, during the period from October 2, 1962 to August 19, 1963. The river contained from 100 to 12,900 algae per milliliter, with extreme variability in numbers at all seasons. Algal nutrient data collected during the 1967 survey show that the major nutrient concentrations, inorganic nitrogen and soluble phosphorus, were not limiting. The samples averaged 1.6 mg/l inorganic N and 0.06 mg/l soluble P at Louisville. The assumption that these nutrients, or turbidity, were not limiting is based on the non-dependent relationship existing between algae and soluble phosphorus, total phosphorus, inorganic nitrogen concentrations and turbidity (Figures 11 to 14). That is, the number of plankton did not increase as the concentrations of nutrients increased and turbidity decreased. During the October 1967 survey, the stations possessing higher nutrient concentrations did not support a larger number of algae, likewise stations having less turbidity did not support greater algal populations than the more turbid stations.

The Salt River enters the Ohio River downstream from the Louisville sewage treatment plant discharge at West Point, Kentucky

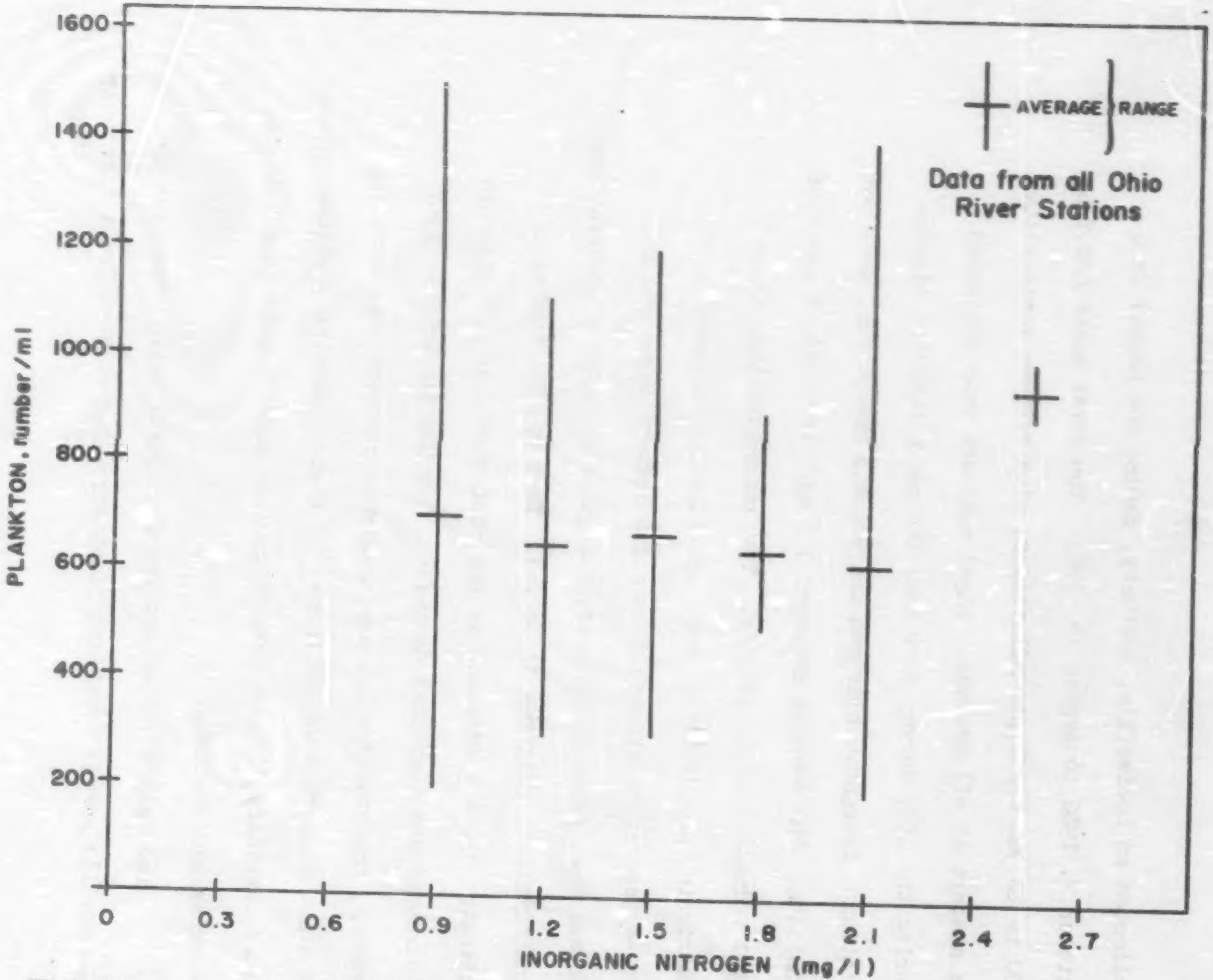

FIGURE 11 NUMBER OF PLANKTON CELLS AT VARIOUS CONCENTRATIONS OF INORGANIC NITROGEN, OCTOBER 1967.

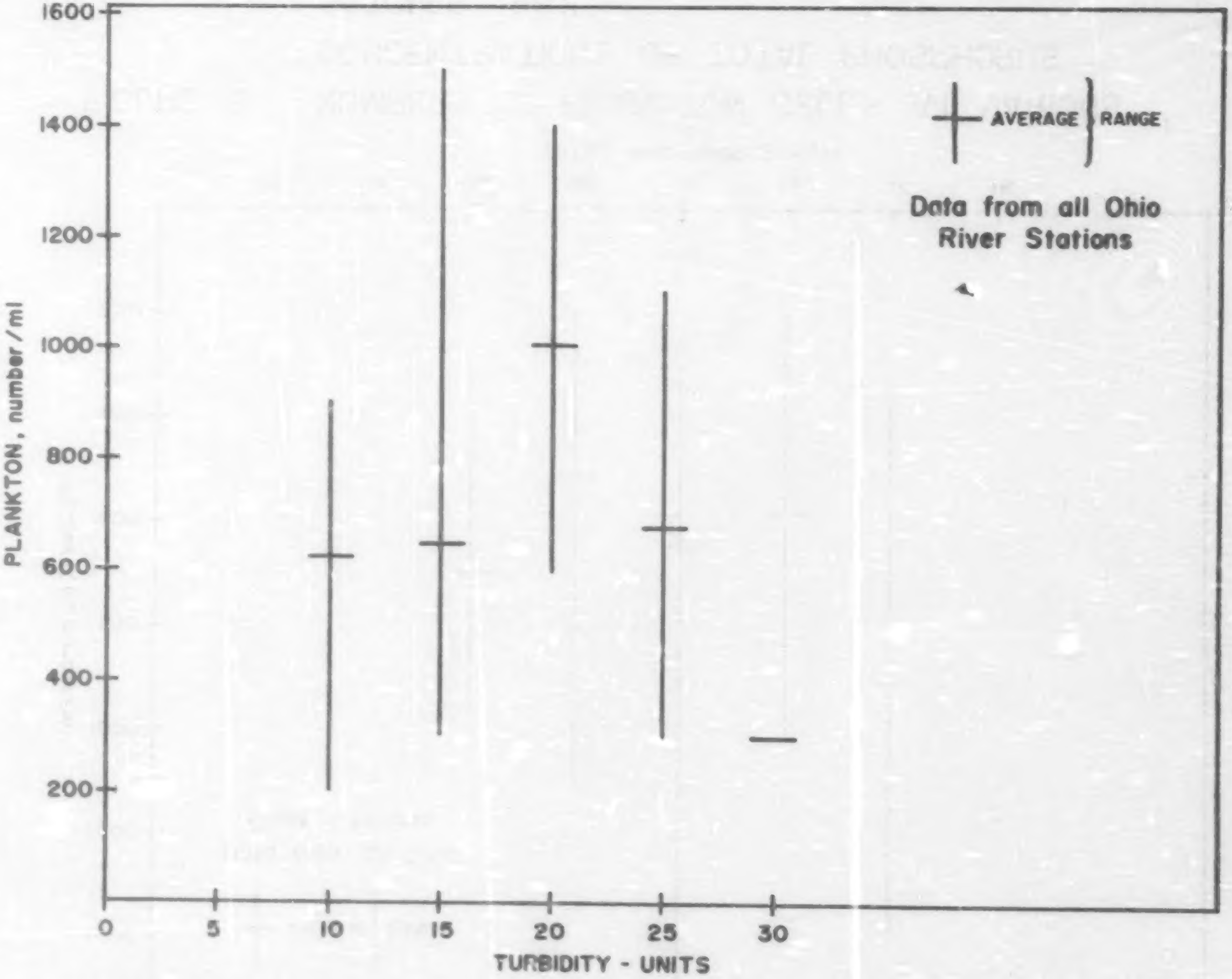

FIGURE 12 NUMBERS OF PLANKTON CELLS AT VARIOUS LEVELS OF TURBIDITY, OCTOBER 1967.

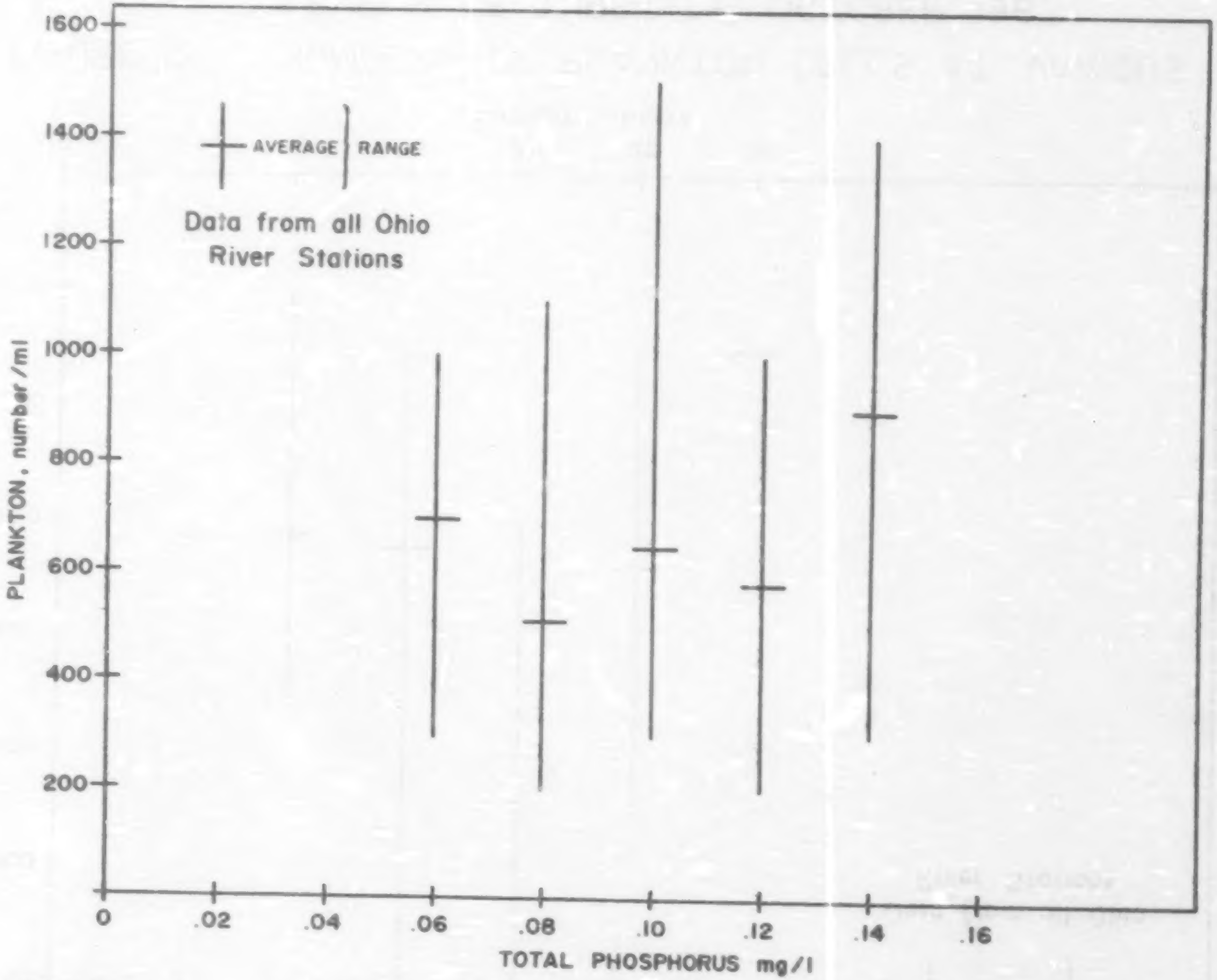

FIGURE 13 NUMBERS OF PLANKTON CELLS AT VARIOUS CONCENTRATIONS OF TOTAL PHOSPHORUS, OCTOBER 1967.

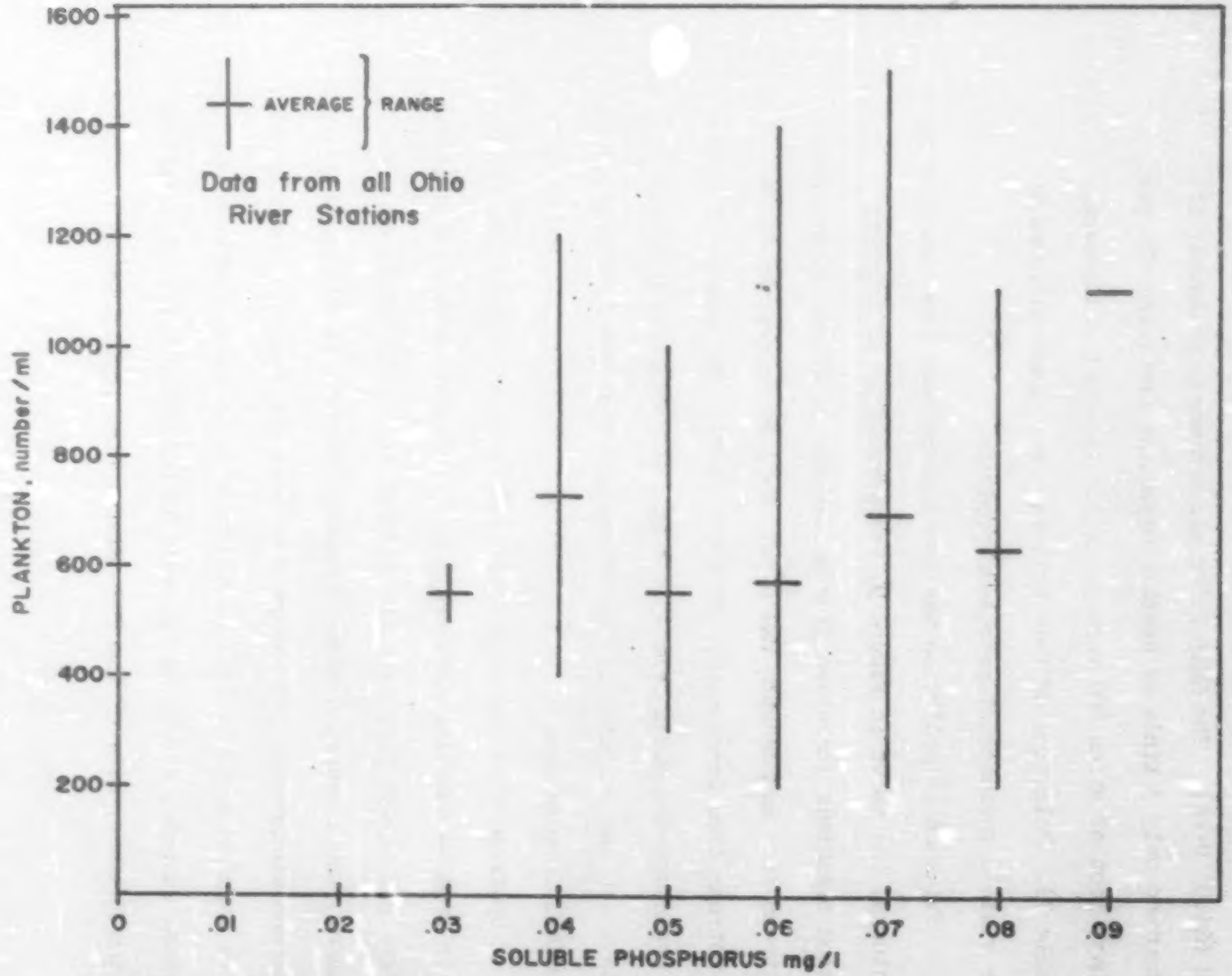

FIGURE 14 NUMBERS OF PLANKTON CELLS AT VARIOUS CONCENTRATIONS OF SOLUBLE PHOSPHORUS, OCTOBER 1967.

(RM 629.9 O-4A). The Salt River was extremely polluted; it supported only 3 kinds of benthic organisms numbering 224 per square foot of which 209 were pollution-tolerant sludgeworms (Table 7). Pollution of this tributary was also confirmed by the visible presence of petroleum products.

Evidence of pollution was found downstream from Brandenburg, Kentucky. As shown in Figure 9, the population of tolerant bottom organisms increased from an average of 20 per square foot upstream from Brandenburg (RM 645.7 O-6) to an average of 94 downstream from Brandenburg (RM 650.8 O-7). The number of kinds of organisms decreased from 7 to 4 at the respective stations. This reach was polluted by the discharges from the Olin Mathieson Chemical Corporation.

Upstream from the Olin Mathieson Chemical Corporation (O-5), cross sectional sampling produced 3 intermediately pollution tolerant midges per square foot near the Indiana shore, 10 midges at mid-channel, and 1 midge, 8 intermediately tolerant clams and 32 pollution tolerant sludgeworms per square foot near the Kentucky shore. Two miles downstream (O-6) from Olin Mathieson Chemical Corporation, cross sectional sampling showed an increase in pollution tolerant organisms on the Kentucky side of the Ohio River. The population of bottom

TABLE 7

BOTTOM ORGANISM DATA*

A. General Summary

Ohio River - October 1967

Number per Square Foot

Station	May-flies	Caddis-flies	Beetles	Clams	Midges	Planaria	Snails	Nema-todes	Leeches	Sludge-worms	Total
0-2 Ind.	-	-	-	3	2	-	-	-	-	17	22
0-2 Ky.	-	-	-	-	5	-	-	-	5	20	30
0-3 Ind.	-	-	-	2	2	-	-	-	-	14	18
0-3 Mid.	-	-	-	-	-	-	-	-	-	8	8
0-3 Ky.	-	-	-	-	-	-	-	-	-	216	216
0-4 Ind.	-	-	-	2	-	-	-	-	-	2	4
0-4 Mid.	10	5	-	2	-	-	2	-	-	5	24
0-4 Ky.	-	-	-	5	71	2	-	-	-	15	93
0-5 Ind.	-	-	-	-	3	-	-	-	-	-	3
0-5 Mid.	-	-	-	-	17	-	-	-	-	-	17
0-5 Ky.	-	-	-	7	2	-	-	-	-	32	41
0-6 Ind.	-	12	-	3	34	-	-	-	-	2	51
0-6 Mid.	-	-	-	-	2	-	-	-	-	-	2
0-6 Ky.	-	-	-	5	19	-	-	-	-	75	99
0-7 Ind.	-	-	-	-	-	-	-	-	-	6	6
0-7 Mid.	-	-	-	2	6	-	-	-	-	2	10
0-7 Ky.	-	2	-	-	22	-	-	-	-	287	311
0-8 Mid.	-	-	-	2	73	-	-	-	-	12	87
0-8 Ky.	-	-	-	-	10	-	-	-	-	124	134
0-9 Ind.	-	-	-	3	8	-	-	-	-	3	14
0-9 Mid.	-	3	1	1	-	1	-	-	-	5	11
0-9 Ky.	-	-	-	-	5	-	-	-	7	97	109
0-10 Ind.	-	-	-	2	-	-	-	-	-	10	12
0-10 Ky.	-	-	-	-	17	-	-	2	-	36	55

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*Specific identifications are listed in Table 7- B.

Ind. - 100 ft. out from the Indiana bank of the Ohio River.

Mid. - Mid-channel.

Ky. - 100 ft. out from the Kentucky bank of the Ohio River.

53-2

TABLE 7

BOTTOM ORGANISM DATA

B. Identification

October 1967

Bottom Organisms Number/sq foot[1]	River Mile Station	599 0-0	600.6 0-1	611.5 0-2A	618 0-3	605.7 0-4	609.9 0-4A[2]	633.5 0-5	645.7 0-6	650.8 0-7	663.5 0-8[3]	667.3 0-9	678.2 0-10	680.9 0-11	689.8 0-12	700.9 0-13	703.6 0-14	710.5 0-15	717.2 0-16
Mayflies																			
Stenonema		-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Tricorythodes		-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagenia		-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Caenis		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caddisflies																			
Hydropsyche		-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Psychomyia		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheumatopsyche		-	-	-	-	-	-	-	3	-	-	1	-	-	-	-	1	-	-
Midges																			
Cryptochironomus		1	1	-	-	-	-	-	-	-	2	1	1	1	-	1	-	1	-
Procladius		2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum		1	-	1	-	1	-	2	1	-	4	-	7	-	3	-	-	2	-
Coelotanypus		-	16	-	-	20	8	-	-	-	-	-	1	2	6	7	-	-	7
Chironomus		-	1	2	-	1	-	-	4	-	1	-	1	-	6	-	1	-	-
Pentaneura		-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harnischia		-	-	-	-	-	-	6	1	2	26	3	3	-	-	-	-	2	1
Spaniotoma		-	-	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-
Tanypus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudochironomus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaoborus		1	1	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-
Clams																			
Corbicula		5	24	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-
Sphaerium		1	6	1	1	2	-	2	3	2	1	1	1	2	2	1	1	3	1
Unionidae		-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-
Beetles																			
Cylloepus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snails		-	-	-	-	1	-	-	-	-	-	-	-	-	1	1	-	-	-
Limpet		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planarian		-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-
Nematodes		-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Leeches		-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Bloodworms		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sludgeworms		13	38	5	76	6	209	11	20	94	4	1	29	1	8	24	4	11	1
Number of Kinds		7	8	4	3	10	3	5	7	4	6	6	8	5	8	6	4	6	5
Total Number per Square Foot[1]		24	61	9	78	38	224	22	34	99	38	9	44	6	29	35	7	20	13
Algae - Number per ml																			
Diatoms		NO SAMPLE	650	NO SAMPLE	250	100	350	500	400	200	150	150	250	150	600	150	500	200	100
Green Algae			150		350	150	30	500	250	150	200	450	200	400	300	450	250	250	600
Flagellates			100		50	50	50	-	-	-	-	50	-	50	50	-	150	-	50
Blue-Greens			-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total			900		650	300	430	1000	650	350	350	650	450	600	950	600	900	450	750

1. Average of 3 samples.
2. One Sample
3. Two Samples

53-2

TABLE 7
(cont'd)

BOTTOM ORGANISM DATA

B. Identification

October 1967

Bottom Organisms Number/sq foot[1]	River Mile Station	723.5 O-17	726.4 O-18	730 O-19	736.6 O-20	741.3 O-21	752.8 O-22[3]	763 O-24	769.8 O-25	778.1 O-26	784 O-27	785.1 O-28[2]	786.8 O-29	791.5 O-30
Mayflies														
Stenonema		-	-	-	1	1	-	-	1	-	-	-	-	-
Tricorythodes		-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagenia		1	-	2	-	1	-	-	-	-	-	-	2	-
Caenis		-	-	-	-	1	1	-	-	-	-	-	-	2
Caddisflies														
Hydropsyche		-	-	-	-	-	-	-	-	-	-	-	-	-
Psychomyia		1	-	-	1	26	-	-	-	-	-	-	-	-
Cheumatopsyche		-	-	2	-	2	-	-	46	10	1	-	1	39
Potamyia		-	-	-	1	-	-	-	-	-	-	-	-	-
Midges														
Cryptochironomus		-	1	3	2	3	-	-	-	3	1	-	-	1
Procladius		-	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum		2	2	4	-	-	1	1	-	-	1	-	-	-
Coelotanypus		5	-	8	-	10	-	9	-	-	-	-	6	-
Chironomus		-	-	1	1	-	-	-	1	-	-	-	2	-
Pentoneura		1	-	-	-	-	-	-	-	-	-	-	-	-
Harnischia		2	2	-	-	5	-	1	-	2	1	-	-	-
Spaniotoma		1	-	-	-	1	-	-	-	-	-	-	-	-
Tanypus		-	-	-	-	-	1	-	-	-	-	-	-	-
Pseudochironomus		-	-	-	-	-	-	3	-	-	-	-	-	-
Chaoborus		-	-	-	-	-	-	1	-	-	-	-	-	-
Clams														
Corbicula		-	-	-	-	-	-	-	-	-	-	-	-	1
Sphaerium		1	6	3	6	2	1	1	4	6	1	20	7	25
Medionidus		-	-	-	-	-	-	-	-	-	-	-	-	-
Beetles														
Cylloepus		-	-	-	-	1	-	-	-	-	-	-	-	-
Snails		-	-	4	-	1	-	-	-	-	-	-	-	-
Limpet		-	-	-	-	-	-	-	-	-	-	-	-	1
Planarian		-	-	-	-	-	-	-	-	-	-	-	-	-
Nematodes		-	-	-	-	-	-	-	-	-	-	-	-	-
Leeches		-	-	-	-	-	-	-	-	-	-	-	1	-
Bloodworms														
Chironomus sp.		-	-	-	-	-	-	2	-	1	-	-	-	-
Sludgeworms		55	6	8	3	17	20	46	2	2	-	7	135	1
Number of Kinds		9	5	9	7	13	3	8	3	6	5	2	7	7
Total Number per Square Foot[1]		69	17	35	15	71	24	64	54	19	5	27	154	70
Algae - Number per ml														
Diatoms		150	50	150	250	NO SAMPLE	150	400	400	100	350	50	550	300
Green Algae		490	250	150	300		350	300	500	250	350	-	400	350
Flagellates		50	-	-	100		-	100	-	100	-	25	50	50
Blue-Green		-	50	-	-		-	-	-	-	-	-	-	-
Total		690	350	300	690		500	800	900	450	700	75	1000	700

1. Average of 3 samples.

2. One Sample

3. Two Samples

animals near the Indiana bank was comprised of 3 clams and 2 sludgeworms per square foot. Mid-channel sampling produced 2 midges per square foot. Near the Kentucky shore, the influence of upstream wastes was evidenced by a population of bottom organisms comprised of 9 midges, 4 clams and 75 pollution tolerant sludgeworms per square foot. Further settling of organic wastes downstream from Station 0-6 was indicated by the increases in phosphorus (150 percent), organic nitrogen (100 percent), and carbon (50 percent) content of the bottom muds. Five miles downstream sludgeworms numbered 287 per square foot whereas, the population of bottom animals at mid-channel and near the Indiana bank remained about the same as upstream. Downstream an additional 17 miles (0-9), the number of sludgeworms was larger than upstream from Olin Mathieson Chemical Corporation indicating that the organic wastes from Olin Mathieson Chemical Corporation settle along the Kentucky bank of the Ohio River for 24 miles.

The slight biological degradation at RM 703.6 (0-14) indicated by a decrease in the number of kinds of organisms (Figure 9) was caused by a shifting sand stream bed.

In the 120-mile reach of river extending from Dam 44 to the confluence with the Green River, no pollutional effects on the bottom animals population were indicated. The population exhibited fluctuations in both the number and kinds of bottom animals, but all were within the variation caused by natural changes in habitat.

In the reach from Dam 44 to the Green River, phytoplankton numbers ranged from 200 to 1,500 algal cells per ml during the 1967 survey period. These values were similar to those observed in October 1939. Plankton populations in both 1939 and 1967 were largely diatoms, principally Melosira.

The population of bottom organisms did not indicate the presence of organic pollution in the Green River at RM 784.3-0.2 (0-28). However, it supported only sparse populations of algae and bottom organisms. The phytoplankton population numbered only 75 per ml. Low algal nutrient concentrations accounted for this sparse plankton population. The population of bottom organisms was comprised of 20 Asiatic clams and 7 sludgeworms per square foot.

Biological degradation was observed in the Ohio River at RM 786.8 (0-29). This station is 1.5 miles downstream from the confluence of the Green River and 5 miles upstream from Evansville. In this reach the bottom substrate was a mixture of silt, leaves and sticks. The sediments contained 0.13 percent organic nitrogen and 1.5 percent carbon, indicating stabilized conditions. The population of bottom organisms was comprised of 88 percent pollution-tolerant organisms and only 2 percent pollution-sensitive organisms. The population of sludgeworms, numbering 135 per square foot was the largest average population found in the Ohio River during the 1967 survey. Downstream at Evansville, Indiana (RM 791.5 0-30), the population of bottom organisms was more representative of clean water with 7 kinds of organisms of which 41 per square foot were clean water mayflies and caddisflies.

FISH OFF-FLAVOR

Unpalatable flavors in many fishes of the Ohio River, during the period from late summer to spring, discourage sport-fishing and decrease fish marketability by commercial fishermen. Many commercial fishermen are forced to fish part time or sell their catch live to "pay lakes" at decreased prices. Fish markets once favoring Ohio River catfish and drum no longer will sell fish taken from the Ohio River. Many species of fish are deemed unsatisfactory for human consumption; to the sport fisherman, off-flavor of the sauger and catfish are particularly offensive. Commercial fishermen complain most about the condition of catfish, freshwater drum and buffalo.

The commercial catch from the Kentucky portion of the Ohio River in 1966 was estimated to be 1,091,457 pounds at a value of $183,639. In 1959, the last year for which sport fishing data are available, an estimated 287,000 sport fishermen harvested 522,504 pounds of fish as table food at a value of $130,626.

Previous studies[1] of commercial fishermen complaints that catfish from the Ohio River had an offensive taste and odor revealed that the compounds producing the off-flavor were present in minute concentrations. In addition, it was concluded that even with the most sensitive analytical instruments available, the compounds could not be detected in fish tissue.

After additional complaints were received by the Evansville, Indiana field station of the Ohio Basin Region, a field reconnaissance was conducted to discuss with commercial fishermen from Indiana and

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[1] Boyle, H. W. Report on Taste/Odor Contamination of Fish from the Ohio River near Tell City, Indiana. Waste Identification and Analysis Activities, FWPCA, U. S. Department of the Interior, pg. 5. 1967.

Kentucky the quality of catfish they were harvesting from the river. It was concluded from these discussions that the most problems occurred downstream from Louisville, Kentucky. In discussions with commercial fishermen upstream from Louisville and in the reach from Owensboro to Evansville, it was concluded that the problem in these areas was intermittent and of short duration.

It is evident from the fish flavor study that contaminated fish were found to lose most of their off-flavor in seven days and to be completely free of all off-flavors in fourteen. Even with gas chromatography, the compounds could not be separated from the natural occurring oils from the fish tissue.

The results of the May 1968 fish taste and odor investigation revealed that a taste panel could differentiate between fish exposed to wastes in the Ohio River as compared to fish held upstream from McAlpine Dam. Fish held upstream from McAlpine Dam did not acquire a significant off-flavor whereas fish placed downstream from RM 612 acquired a strong off-flavor.

In July the investigation was expanded to include the entire Ohio River, and this study showed that both caged and native fish from the West Virginia sites generally possessed a high degree of off-flavor whereas fish from the Ohio River near Paducah and Cairo were of fairly acceptable quality and fish from the Louisville area and dams 48 and 50 were of borderline quality (Figure 15). The remaining sites along the Kentucky borderline were of unacceptable quality.

Another investigation in October indicated that three reaches of the Ohio River contain chemicals that produced sufficient off-flavor in catfish to make them unacceptable. These areas were immediately downstream from Pittsburgh, Pennsylvania; from Parkersburg, West Virginia to Gallapolis, Ohio; and from Louisville to Owensboro, Kentucky (Figure 15).

Because of the large quantities of slimes resulting from the Louisville sewage treatment plant that clogged wire mesh baskets and suffocated the fish, wooden boxes with large holes were employed during this October study. Test fish were exposed for both 48 and 336 hours at 4 test sites. It was found that 48 hours was sufficient to produce the same degree of off-flavor as 336 hours.

The degree of off-flavor caused by individual effluents is shown in Figure 15. For example, the effect of the Louisville sewage treatment plant effluent (RM 612 0) can be ascertained

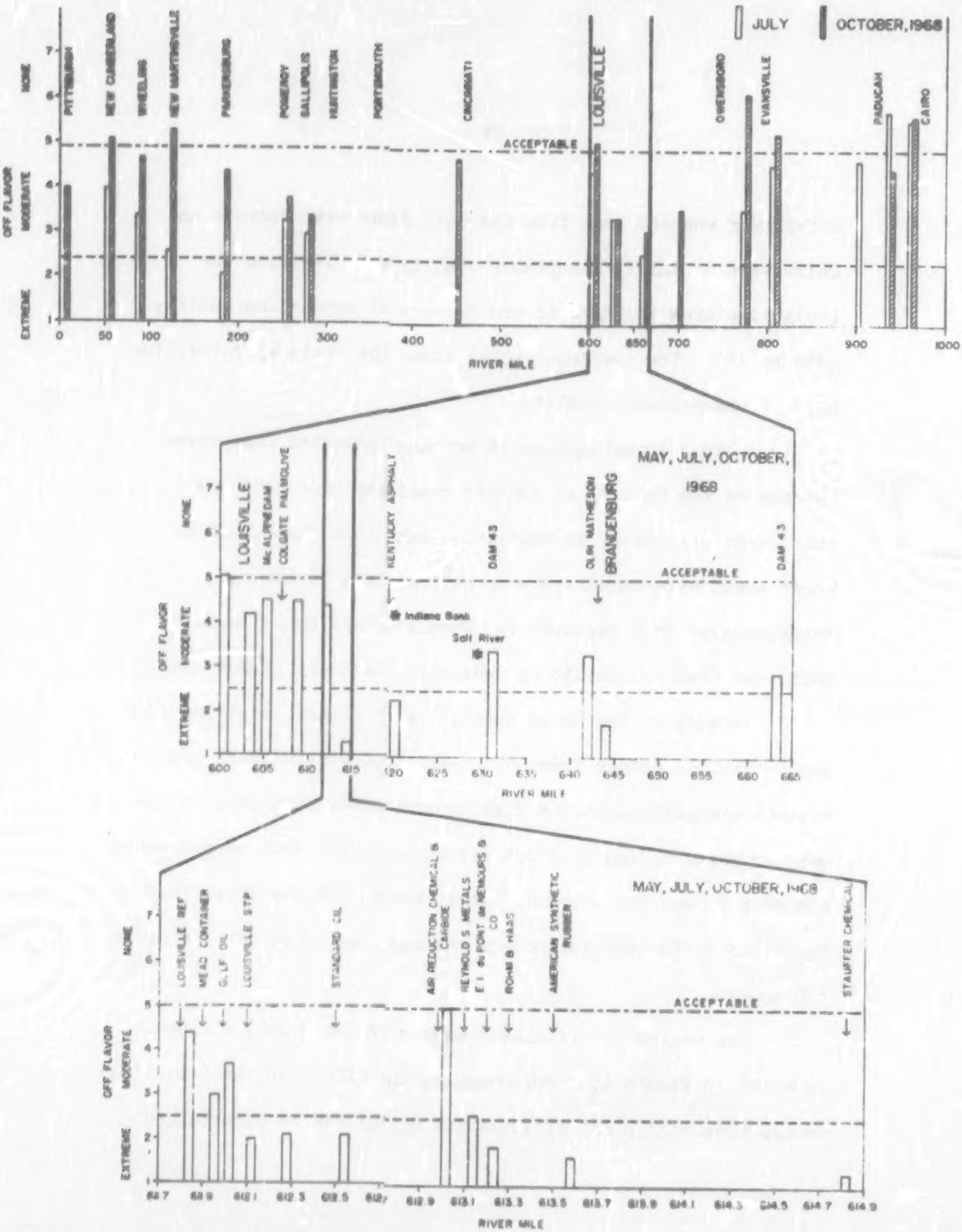

FIGURE 15. DEGREE OF OFF-FLAVOR OF CAGED CHANNEL CATFISH, OHIO RIVER, 1968.

from the lower portion of Figure 15. The values at the stations just upstream (RM 612) and downstream (RM 612.1) decreased from 3.7 to 2.0. The fish held downstream from the Louisville sewage treatment plant were in the extreme off-flavor category. Fish held in the eight mile reach (RM 612 - 620) were also adversely affected by the discharge from E. I. duPont de Nemours and Co., American Synthetic Rubber Corp., and Stauffer Chemical Corp. One anomaly was noted downstream from the Air Reduction Chemical and Carbide Company where an apparent improvement in the flavor of fish held at river mile 613 occurred. From observations, it was apparent that materials contained in this effluent combined with substances in the river to form a precipitate which subsequently settled. It is possible that some of the substances producing the off-flavor in fish were likewise precipitated within 500 ft. downstream from the effluent (RM 613).

Fish with unacceptable flavor occurred in the Ohio River. The reaches of the Ohio River that produced fish with extreme off-flavor were downstream from the Louisville sewage treatment plant RM 612) to Dam 43 (RM 633) and downstream from the Olin Mathieson Chemical Corporation to Owensboro, Ky.

The results from this intensive investigation and all other exposure studies (Table 8) led to the following conclusions:

Table 8-A

Taste Panel Evaluation of Ohio River Catfish--1968

Mean Flavor Scores

Scale: 7 highest; 1 lowest score possible

		May		July		October			
City	River Mile	Flavor	Desirability	Odor	Flavor	Appearance	Odor	Flavor	Overall
Pittsburgh	6.2	-	-	-	-	6.2	4.8	4.0	4.0
New Cumberland	54.4	-	-	5.2	4.0	6.6	6.2	5.2	5.3
Wheeling	84.3	-	-	5.0	3.4	6.6	5.3	4.7	4.7
New Martinsville	127	-	-	4.4 5.3	2.6N 2.7	7.2	6.2	3.3	5.5
Parkersburg	185	-	-	5.6 4.8	4.0N 2.1	6.3	4.9	4.4	4.4
Pomery	254	-	-	4.8 6.4	3.3N 4.7	6.8	5.2	3.8	4.2
Gallipolis	276	-	-	5.1 5.6	3.0N 4.3	5.5	4.0	3.4	3.6
New Richmond	450	-	-	-	-	7.0	5.0	4.7	4.9
u.s. Louisville	597.8	4.6	3.2	-	-	6.3 -	5.6 -	5.1 5.2	4.3 4.0
d.s. Shell Oil	602.7	5.3	3.4	-	-	-	-	-	-
d.s. Nat'l Oil	602.8	3.4	2.3	-	-	-	-	-	-
d.s. American Bituminous Asphalt	602.9	4.3	3.4	-	-	-	-	-	-
d.s. Jeff. Boat Wks.	604.2	3.2	2.3	-	-	-	-	-	-
McAlpin Dam	606	-	-	4.9	4.4	5.4	4.9	5.2	4.9
Indiana Bank Colgate-Palmolive	608	-	-	-	-	-	-	4.0	2.9 2wk.
Indiana Bank Socony Vacuum Oil	609.4	4.6	3.4	-	-	-	-	-	-
Indiana Bank Public Service Company	610	-	-	-	-	5.3	4.7	3.9 5.0	4.0 4.0
Louisville Ref.	611.8	-	-	-	-	3.4	4.6	3.7 5.1	3.6 3.9
Mead Container	611.9	-	-	-	-	5.4	3.1	2.1 3.8	2.4 2.8

u. s. - upstream from
d. s. - downstream from
N - Native

Table 8-A
(contd)

City	River Mile	May		July		October			
		Flavor	Desira-bility	Odor	Flavor	Appear-ance	Odor	Flavor	Overall
Gulf Ref.	612	-	-	-	-	4.2	3.2	2.8 4.6	2.6 3.3
Louisville STP	612.1	-	-	-	-	5.5	2.7	2.0	1.6
Aetna Oil	612.2	-	-	-	-	-	-	2.1	1.5
Standard Oil	612.5	2.4	1.8	-	-	4.7	3.4	2.2	2.1
Air Reduction Chem. Carbide	613	-	-	-	-	5.5	5.6	5.0	3.2
Reynolds Met.	613.1	-	-	-	-	6.5 - -	2.3 - -	1.9 2.5 3.3	2.6 1.9 2wk. 2.4
E. I. duPont de Nemours	613.2	-	-	-	-	2.1	2.1	1.9	2.1
Rohm & Haas	613.3	-	-	-	-	-	-	-	-
Am. Synthetic Rubber	613.6	-	-	-	-	4.6 -	1.3 -	1.3 1.7	1.5 1.5 2wk
Stauffer Chemical	614.8	1.3	1.00	-	-	-	-	-	-
Ky. Asphalt	620.5	-	-	-	-	5.5 -	2.7 -	2.0 2.6	2.1 1.6
Indiana Bank	620.5	-	-	-	-	5.8	5.3	4.2	4.3
Dam 43	633	-	-	4.2	3.4	6.2	4.3	3.4	3.6
u.s. Olin Mathieson	642	2.7	1.8	-	-	4.8 5.0 - -	2.5 4.0 - -	2.3 3.9 3.9 4.2	2.1 3.9 2wk 2.9 2wk 3.0
d.s. Olin Mathieson	644	1.7	1.2	-	-	4.2 -	1.4 -	1.3 2.2	1.1 1.6
Dam 44 Leavenworth	663	-	-	4.2	2.6	6.0	4.1	3.2	3.8
45 Rome	703	-	-	-	-	5.6	3.8	3.6	3.8
47 Newburg	777	-	-	4.2	3.6	6.1	6.0	6.2	6.1
48 Henderson	809	-	-	5.0	4.6	6.4	5.4	5.3	5.3
50 Weston	876.8	-	-	-	-	5.9	5.0	5.1	4.9
51 Galcondia	903	-	-	5.1	4.7	-	-	-	-

u. s. - upstream from
d. s. - downstream from

Table 8-A
(contd)

City	River Mile	May		July		October			
		Flavor	Desirability	Odor	Flavor	Appearance	Odor	Flavor	Overall
52 Paducah	938	-	-	6.0	5.8	6.2	4.6	4.5	4.5
53 -	962.6	-	-	6.1	5.6	5.9	5.7	5.7	5.9
Salt River	629.8-1.0	3.3	2.1	-	-	-	-	-	-

Table 8-B

Taste Panel Evaluation of Ohio River Catfish--1969

Mean Flavor Scores

Tested by Oregon State University

Scale: 7 highest; 1 lowest score possible

City	River Mile	July		October	
		Flavor	Desirability	Flavor	Desirability
Pittsburgh	6.2	3.7	2.5	3.8	2.6
New Cumberland	54.4	4.3	3.0	3.8	2.7
Wheeling	84.3	4.3	3.0	4.5	3.8
New Martinsville	127	4.7	3.6	4.6	3.2
Parkersburg	185			4.9	3.7
Belleville	203.9	4.1	3.0	3.6	2.4
Racine	237.3	4.7	3.6	3.8	2.3
Gallipolis	279.2	3.8	2.5	3.0	1.9
Huntington	305	4.0	2.8	2.8	2.0
Green-up	341.4	4.3	3.0	3.1	2.0
Meldahl	446.2	5.4	3.0	4.3	3.0
Markland	531.5	4.3	2.7	3.6	2.1
McAlpine	606	4.5	2.8	4.7	3.4
Dam 43	633	4.6	3.0	4.3	3.0
Dam 44	663	4.6	3.0	3.8	2.4
Dam 45	710	-	-	4.3	3.0
Dam 47	777.7	5.2	3.6	4.6	3.3

60-2

Table 8-B
(contd)

City	River Mile	July Flavor	July Desirability	October Flavor	October Desirability
Dam 48	809.0	-	-	4.8	3.8
Dam 51	903.1	-	-	3.8	2.6
Dam 52	938.9	-	-	5.0	3.7
Dam 53	962.6	-	-	5.5	4.3
Control		4.7	3.4	5.5	4.4

1. Caged catfish held upstream from Louisville, Kentucky (RM 597.9) and at McAlpine Dam (RM 606) were of acceptable quality.
2. Fish held in cages downstream from Colgate-Palmolive, Jeffersonville, Indiana; Louisville Refinery; Gulf Refining Company; Aetna Oil; Standard Oil; Air Reduction Chemical Carbide; Reynolds Metals Company; and Kentucky Asphalt, all of Louisville, Kentucky, did not possess a higher degree of off-flavor as compared to the fish upstream from each of these installations.
3. Fish held in cages downstream from Mead Container, Louisville, Kentucky, had an average score of 2.9 which indicates a very strong off-flavor. The quality of these fish was 1.4 units lower than fish held upstream. Toxicity killed some of the caged catfish at a depth of one foot, 300 feet downstream from the Mead Container outfall.
4. Caged catfish held 800 feet downstream from the Louisville sewage treatment plant were of unacceptable quality. The fish scored 1.7 units lower than the fish held upstream from the effluent. The compounds contained in the Louisville

sewage treatment plant effluent lowered the quality of catfish more than any other pollutional sources tested.

5. Wastes from the Reynolds Metals Company, Louisville, Kentucky, killed half of the fish in cages at a depth of one foot, 400 feet downstream, whereas fish held in cages immediately upstream from the effluent were not killed.
6. All fish held in cages for 48 hours at a depth of one foot were killed 1400 feet downstream from the effluents from E. I. duPont de Nemours and Company, Louisville, Kentucky. Fish held in cages at other depths had a stronger off-flavor than fish held in cages upstream from the effluents. The off-flavor of the fish was quite high in this area, thus making the numerical decrease in quality minimal. Fish downstream from E. I. duPont de Nemours and Company scored .7 units poorer than fish upstream from the outfall.
7. The quality of caged catfish was further deteriorated 800 feet downstream from the American Synthetic Rubber Corporation, Louisville, Kentucky. Fish held in cages here scored .25 units poorer than fish held immediately upstream from this plant.

There is the possibility that wastes from Rohm and Haas Company and B. F. Goodrich contained substances that could produce off-flavors in catfish. However, their effluents could not be located and any effect would be combined with that of American Synthetic Rubber.

8. Four-hundred-fifty feet downstream from the Stauffer Chemical Corporation, Louisville, Kentucky, effluent, wastes were toxic at all depths during all surveys except for one occasion; **fish immediately upstream were** not killed. The fish that did survive were of the lowest quality encountered in any of these surveys. The wastes from the Stauffer Chemical Corporation lowered the quality by .35 units. This value is also the minimum found because of the accumulative effects from this and other upstream wastes.

9. Wastes from the Olin Mathieson Chemical Corporation, Brandenburg, Kentucky, impart increased off-flavor to caged catfish one mile downstream. Caged catfish upstream from Olin Mathieson Chemical Corporation had a moderate off-flavor, but those exposed developed an extreme off-flavor--a change of 1.5 units. Caged fish were killed 500 feet downstream from

the Olin Mathieson discharge, whereas fish immediately upstream survived. Twenty miles downstream the quality of caged catfish was still less than that of test fish upstream from Olin Mathieson Chemical Corporation.

10. Wastes from Mead Container; Louisville sewage treatment plant; E. I. duPont de Nemours and Company; American Synthetic Rubber Corporation; Stauffer Chemical Company; and Olin Mathieson Chemical Corporation contained sufficient taste producing substances to cause catfish to be of unacceptable quality (unpalatable) from Louisville to Evansville, a distance of 190 miles, in July, and from Louisville to Owensboro, a distance of 150 miles, in October.

APPENDIX A

INDIANA WATER QUALITY STANDARDS

Pursuant to due publication of notice and public hearing required by the provisions of the Acts of 1945, Chapter 120, as found in Burns' IND. STAT. ANN., (1961 Repl.), Section 60-1501, et seq., the Stream Pollution Control Board of the State of Indiana at a special meeting held at 1330 West Michigan Street, Indianapolis, Indiana, on June 5, 1967, at which meeting a quorum of members was present, as provided by the Acts of 1943, Chapter 214, as amended by Acts of 1945, Chapter 132, Section 2, as found in Burns' Indiana Statutes, 1961 replacement 68-519, unanimously adopted the following new rules:

REGULATION SPC 1R
Water Quality Standards for Waters of Indiana

MINIMUM CONDITIONS APPLICABLE TO ALL WATERS AT ALL PLACES AND AT ALL TIMES

1. Free from substances attributable to municipal, industrial, agricultural or other discharges that will settle to form putrescent or otherwise objectionable deposits.
2. Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial, agricultural or other discharges in amounts sufficient to be unsightly or deleterious.

3. Free from materials attributable to municipal, industrial, agricultural or other discharges producing color, odor or other conditions in such degree as to create a nuisance.
4. Free from substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.

STREAM-QUALITY CRITERIA
FOR PUBLIC WATER SUPPLY AND FOOD PROCESSING INDUSTRY

The following criteria are for evaluation of stream quality at the point at which water is withdrawn for treatment and distribution as a potable supply:

1. Bacteria: Coliform group not to exceed 5,000 per 100 ml as a monthly-average value (either MPN or MF count); nor exceed this number in more than 20 percent of the samples examined during any month; nor exceed 20,000 per 100 ml in more than five percent of such samples.
2. Threshold-odor number: Taste and odor producing substances, other than naturally occurring, shall not interfere with the production of a finished water by conventional treatment consisting of coagulation, sedimentation, filtration and chlorination. The threshold odor number of the finished water must be three or less.

3. **Dissolved solids:** Other than from naturally occurring sources not to exceed 500 mg/l as a monthly-average value, nor exceed 750 mg/l at any time. Values of specific conductance of 800 and 1,200 micromhos/cm (at 25°C.) may be considered equivalent to dissolved-solids concentrations of 500 and 750 mg/l.

4. **Radioactive substances:** Gross beta activity (in the known absence of Strontium-90 and alpha emitters) not to exceed 1,000 picocuries per liter at any time.

5. **Chemical constituents:** Not to exceed the following specified concentrations at any time:

Constituent	Concentration (mg/l)
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium (hexavalent)	0.05
Cyanide	0.025
Fluoride	1.0
Lead	0.05
Selenium	0.01
Silver	0.05

FOR INDUSTRIAL WATER SUPPLY

The following criteria are applicable to stream water at the point at which the water is withdrawn for use (either with or without treatment) for industrial cooling and processing:

1. Dissolved oxygen: Not less than 2.0 mg/l as a daily-average value, nor less than 1.0 mg/l at any time.
2. pH: Not less than 5.0 nor greater than 9.0 at any time.
3. Temperature: Not to exceed 95°F. at any time.
4. Dissolved solids: Other than from naturally occurring sources not to exceed 750 mg/l as a monthly-average value, nor exceed 1,000 mg/l at any time. Values of specific conductance of 1,200 and 1,600 micromhos/cm (at 25°C.) may be considered equivalent to dissolved solids concentrations of 750 and 1,000 mg/l.

FOR AQUATIC LIFE

The following criteria are for evaluation of conditions for the maintenance of a well balanced, warm-water fish population. They are applicable at any point in the stream except for areas immediately adjacent to outfalls. In such areas cognizance will be given to opportunities for the admixture of waste effluents with river water.

1. Dissolved oxygen: Not less than 5.0 mg/l during at least 16 hours of any 24-hour period, nor less than 3.0 mg/l at any time.
2. pH: No values below 6.0 nor above 9.0 and daily-average (or median) values preferably between 6.5 and 8.5.

3. *Temperature*: Not to exceed 93°F. at any time during the months of April through November, and not to exceed 60°F. at any time during the months of December through March.

4. *Toxic substances*: Not to exceed one-tenth of the 96-hour median tolerance limit obtained from continuous flow bioassays where the dilution water and toxicant are continuously renewed, except that other application factors may be used in specific cases when justified on the basis of available evidence and approved by the appropriate regulatory agencies.

5. *Taste and Odor*: There shall be no substances which impart unpalatable flavor to food fish, or result in noticeable offensive odors in the vicinity of the water.

6. *Trout streams*: In addition, the following criteria are applicable to those waters designated for put-and-take trout fishing:

   (a) *Dissolved oxygen*: Not less than 6.0 mg/l as a daily-average value, nor less than 4.0 mg/l at any time.

   (b) *pH*: Not less than 6.5 nor greater than 8.5 at any time.

   (c) *Temperature*: Not to exceed 65°F. (However, slightly higher temperatures may be tolerated with higher dissolved oxygen content than specified.

FOR RECREATION

The following criteria are for evaluation of conditions at any point in waters designated to be used for recreational purposes:

1. Whole body contact: Coliform group not to exceed 1,000 per 100 ml as a monthly-average value (either MPN or MF count) during any month of the recreational season; nor exceed this number in more than 20 percent of the samples examined during any month of the recreational season; nor exceed 2,400 per 100 ml (either MPN or MF count) on any day during the recreational season. The months of April through October, inclusive, are designated as the recreational season.
2. Partial body contact: Coliform group not to exceed 5,000 per 100 ml as a monthly-average value (either MPN or MF count); nor exceed this number in more than 20 percent of the samples examined during any month; nor exceed 20,000 per 100 ml in more than five percent of such samples.

FOR AGRICULTURAL OR STOCK WATERING

Criteria are the same as those shown for minimum conditions applicable to all waters at all places and at all times.

Note 1: Unless otherwise specified, the term average as used herein means an arithmetical average.

Note 2: The analytical procedures used as methods of analyses to determine the chemical, bacteriological, biological, and radiological quality of waters sampled shall be in accordance with the latest edition of Standard Methods for the Examination of Water and Wastewater or other methods approved by the Indiana Stream Pollution Control Board and the Federal Water Pollution Control Administration.

APPENDIX B

KENTUCKY WATER QUALITY STANDARDS

WATER QUALITY STANDARDS FOR INTERSTATE WATERS

Relates to KRS 224.010 to 224.210 and 224.990

Pursuant to the authority vested in the Water Pollution Control Commission by KRS 224.040, the following regulation is adopted:

Section 1. MINIMUM CONDITIONS APPLICABLE TO ALL INTERSTATE WATERS.

The following minimum conditions shall apply at all places and at all times to the interstate rivers within the jurisdiction of the Commonwealth of Kentucky which are as follows: The Mississippi, the Ohio, the Tennessee, the Cumberland (both lower and upper portions) and the Big Sandy (including the Tug and Levisa Forks):

(1) Free from substances attributable to municipal, industrial or other discharges or agricultural practices that will settle to form putrescent or otherwise objectionable sludge deposits.

(2) Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges or agricultural practices in amounts sufficient to be unsightly or deleterious.

(3) Free from materials attributable to municipal, industrial or other discharges or agricultural practices producing color, odor or other conditions in such degree as to create a nuisance.

(4) Free from substances attributable to municipal, industrial or other discharges or agricultural practices in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.

Section 2. STREAM USE CLASSIFICATION.

In addition to the minimum conditions set forth in Section 1, the following specific stream use classifications shall govern where applicable.

(1) Public Water Supply and Food Processing Industries

The following criteria are applicable to water at the point at which water is withdrawn for use for a public water supply or by a food processing industry:

(a) Bacteria: Coliform group not to exceed 5,000 per 100 ml as a monthly arithmetical average value (either MPN or MF count); nor exceed this number in more than 20 percent of the samples examined during any month; nor exceed 20,000 per 100 ml in more than five percent of such samples.

(b) Threshold-odor number: After normal treatment to be less than 3, generally the value will be less than 24 in the raw water.

(c) Dissolved solids: Not to exceed 500 mg/1 as a monthly average value, nor exceed 750 mg/1 at any time [Values of specific conductance of 800 and 1,200 micromhos/cm (at 25°C.) may be considered equivalent to dissolved solids concentrations of 500 and 750 mg/1.]

(d) Radioactive Substances: Gross beta activity not to exceed 1,000 picocuries per liter, (pCi/1), nor shall activity from dissolved Strontium 90 exceed 10 pCi/1, nor shall activity from dissolved alpha emitters exceed 3 pCi/1.

(e) Chemical constituents: Not to exceed the following specified concentrations at any time:

Constituents	Concentration(mg/1)
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium (hexavalent)	0.05
Cyanide	0.025
Fluoride	1.0
Lead	0.05
Selenium	0.01
Silver	0.05

(2) Industrial Water Supply

The following criteria are applicable to water at the point at which water is withdrawn for use, either with or without treatment, for industrial cooling and processing (other than food processing):

(a) pH: Not less than 5.0 nor greater than 9.0 at any time.

(b) Temperature: Not to exceed 95°F. at any time.

(c) Dissolved Solids: Not to exceed 750 mg/l as a monthly average value, nor exceed 1,000 mg/l at any time. [Values of specific conductance of 1,200 and 1,600 micromhos/cm (at 25°C.) may be considered equivalent to dissolved-solids concentrations of 750 and 1,000 mg/l.]

(3) Aquatic life

The following criteria are for evaluation of conditions for the maintenance of well balanced, indigenous fish populations. These criteria shall be applicable to all waters here considered except for areas immediately adjacent to outfalls. In such areas cognizance will be given by the Water Pollution Control Commission to opportunities for the admixture of the effluents from such outfalls with the waters of the River.

(a) Dissolved oxygen: Not less than 5.0 mg/l during at least 16 hours of any 24-hour period, nor less than 3.0 mg/l at any time.

(b) pH: No values below 5.0 nor above 9.0 and preferably between 6.5 and 8.5.

(c) Temperature: Not to exceed 93°F. at any time during the months of May through November, and not to exceed 73°F. at any time during the months of December through April.

(d) Toxic substances: Not to exceed one-tenth of the 48-hour median tolerance limit, except that other limiting concentrations may be used in specific cases when justified on the basis of available evidence and approved by the Water Pollution Control Commission.

(4) Recreation

The following criterion is for evaluation of conditions at any point in waters designated by the Water Pollution Control Commission to be used for recreational purposes, including but not limited to such water-contact activities as swimming and water skiing:

Bacteria: Coliform group not to exceed 1,000 per 100 ml as a monthly arithmetical average value (either MPN or MF count); nor exceed this number in more than 20 percent of the samples examined during any month; nor exceed 2,400 per 100 ml (either MPN or MF count) on any day.

(5) Agricultural

No criteria in addition to the minimum conditions enumerated in Section I are proposed for the evaluation of stream quality at the point at which water is withdrawn for agricultural and stock watering use.

APPENDIX C

LATERAL MIXING IN THE OHIO RIVER DOWNSTREAM FROM LOUISVILLE, KENTUCKY

Differences between dissolved oxygen concentrations for quarter point samples and the occurrence of a 7-1/2 mile-long sludge bank downstream from the Louisville, Kentucky sewage treatment plant outfall, indicated that lateral mixing (i.e. perpendicular to the direction of water flow) is quite limited in the Ohio River during low flow periods. Calculation of lateral mixing concentration profiles has been performed using a theoretical equation.

The dispersion equation used for this analysis was developed by Glover(1). The Equation is:

$$c_q = \frac{q \exp\left(- \frac{U y^2}{4 E_y x}\right)}{D (\pi E_y U x)^{1/2}} \qquad (1)$$

where: c_q = concentration of conservative substance.

q = mass introduction rate of conservative substance.

U = stream velocity.

y = distance from bank perpendicular to the direction of flow.

x = distance downstream from point of introduction of conservative substance.

E_y = lateral dispersion rate coefficient.

D = mean stream depth.

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Equation (1) was derived for streams of unlimited width but can be adopted to natural streams. It can be applied directly until the quantity

$$\frac{B}{(4\ E_y\ t)^{1/2}} = 2 \qquad (2)$$

where: t = time of flow downstream.

B = stream width.

E_y = lateral dispersion rate.

When this condition occurs, the dispersing substance has been transported from one bank to the opposite bank and the equation no longer applies directly. To account for boundary conditions downstream from this point, Glover(1) recommends the "method of images" which he describes fully.

In order to use Equation (1), it is necessary to evaluate the necessary coefficients. The lateral dispersion coefficient E_y is the most difficult to evaluate. Fischer(2,3) recommended the use of an equation developed by Elder to evaluate E_y. This equation is:

$$E_y = 0.23\ D\ U^* \qquad (3)$$

where U* = shear velocity.

In a later article, Fischer(4) reported that for the Missouri River a coefficient of 0.6 rather than 0.23 in Equation (2) better fit the observed data. This he partially attributed to the hydraulic effects of river bends.

The sheer velocity (U^*) in Equation (3) can be estimated by the equation:

$$U^* = \sqrt{\frac{\tau_o}{\rho}} = \frac{(g)^{1/2}}{C_1} U \qquad (4)$$

where τ_o = fluid sheer stress at a boundary.

ρ = fluid density.

g = acceleration of gravity.

C_1 = Chezy friction factor.

U = mean velocity.

The Ohio River has a much lower velocity than the Missouri River at low flows making the effects of bends not nearly as significant.

To determine the effects of river bends and to observe the sensitivity of Equation (1) to changes in E_y, calculations were performed using values of 0.23, 0.46 and 0.60 in Equation (2).

An example of the computations for lateral mixing in the Ohio River downstream from Louisville, Kentucky, follows:

Average width = 1600 ft.

Average depth = 17.5 ft.

Cross Sectional Area = 28,000 ft.^{2}

Velocity = 1.8 fps.

Hydraulic slope = 0.0000224 ft./ft.

(3.1 ft. drop in 26.2 miles - C.E. gage records for October 2 - 14, 1968 survey period.)

Flow = 46,700 cfs

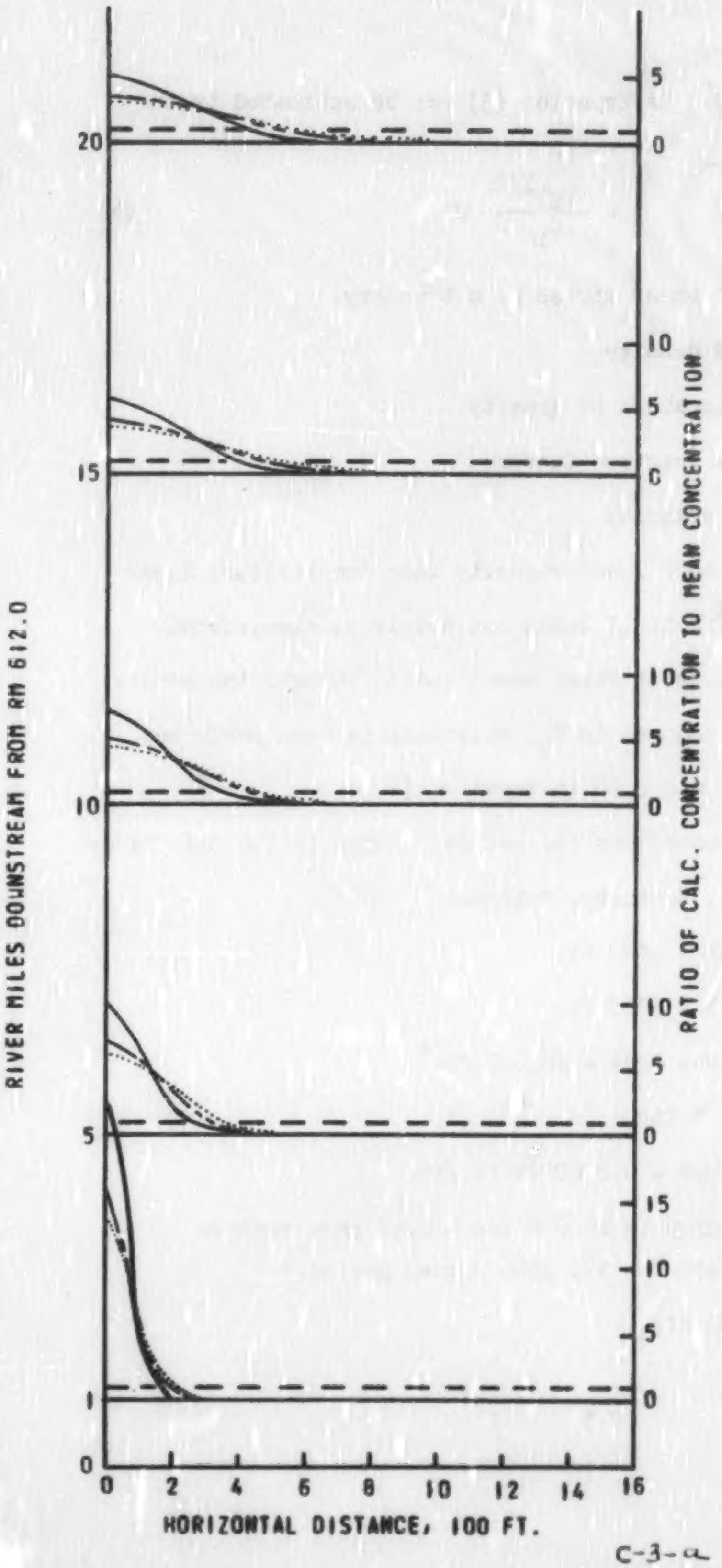

FIGURE C-1
CALCULATED LATERAL MIXING
OHIO RIVER AT LOUISVILLE, KY.

$$n = \frac{1.486}{Q} \; A \, R^{2/3} \, S^{1/2}$$

$$n = \frac{1.486}{46{,}700} (28{,}000)(17.5)^{2/3} \; (0.0000224)^{1/2}$$

$$\underline{n = 0.0284}$$

$$\underline{C_1} = \frac{1.486}{n} R^{1/6} \simeq \underline{85.5}$$

$$\frac{U}{U^*} = \frac{C_1}{(g)^{1/2}} = \frac{85.5}{5.675} = 15.1$$

$$\underline{U^*} = \frac{1.8}{15.1} = \underline{0.119}$$

$$\underline{E_y} = 0.23 \, DU^* = \underline{0.479 \;\; Ft^2/sec}$$

$$\underline{E_y} = 0.46 \, DU^* \quad \underline{0.958 \; Ft^2/sec}$$

$$\underline{E_y} \quad 0.60 \, DU^* \quad \underline{1.250 \; Ft^2/sec}$$

Computations were performed with an assumed loading of 100 lbs./sec of a conservative substance entering at River Mile 612.0 (the outfall location of the Louisville Sewage Treatment Plant). If this loading were immediately diluted by the entire river flow, the average concentration would be 34.3 mg/l. All calculated concentrations were then expressed as a ratio to this average (Figure C-1).

The peak concentration of the constituent decreases as the waste moves downstream and is dispersed toward the opposite river bank. Assuming that the lateral dispersion rate in the Ohio is approximated by E_y = 0.958 Ft^2/sec, the peak concentration near the bank would still be

3.5 times greater than the mean concentration 20 miles downstream; the concentration out 1200 feet (the 3/4 point) would only be 0.6 percent of the mean.

Although these curves are theoretical and neglect density currents, wind mixing and the mixing caused by the passage of tows, the general form of the curves simulates the actual.

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(3) Fischer, H. B., "The Mechanics of Dispersion in Natural Streams," J. Hyd. Div., A.S.C.E., Vol. 93, No. Hy-6, November 1967.

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APPENDIX D

TIME-OF-WATER TRAVEL

Calculation of the time-of-water travel from Louisville, Kentucky, to Evansville, Indiana, was accomplished using the volume-displacement method. Cross-section depths were taken from maps furnished by the U. S. Army Corps of Engineers. The width distance between depth readings were measured manually from the charts with a scale. A cross-section interval of one-half mile was used.

The method of calculation for the cross-section area assumed straight lines existed between each bottom point. This assumption allows the cross-section to be dissected into a series of trapezoids. The total area was calculated as the sum of these trapezoids. The water volume between stations was calculated by averaging the end areas and multiplying by the one-half mile distance between cross-sections. The time-of-travel through each one-half mile segment is the segment volume divided by the flow rate.

The accuracy of time-of-travel estimates by this method depends on how close actual conditions meet the necessary assumptions for the calculations. The primary assumptions are listed below:

1. The straight line assumed between depth points represents a good average of actual conditions.
2. The cross-sections are relatively uniform between stations so that an average end-area calculation method is adequate.

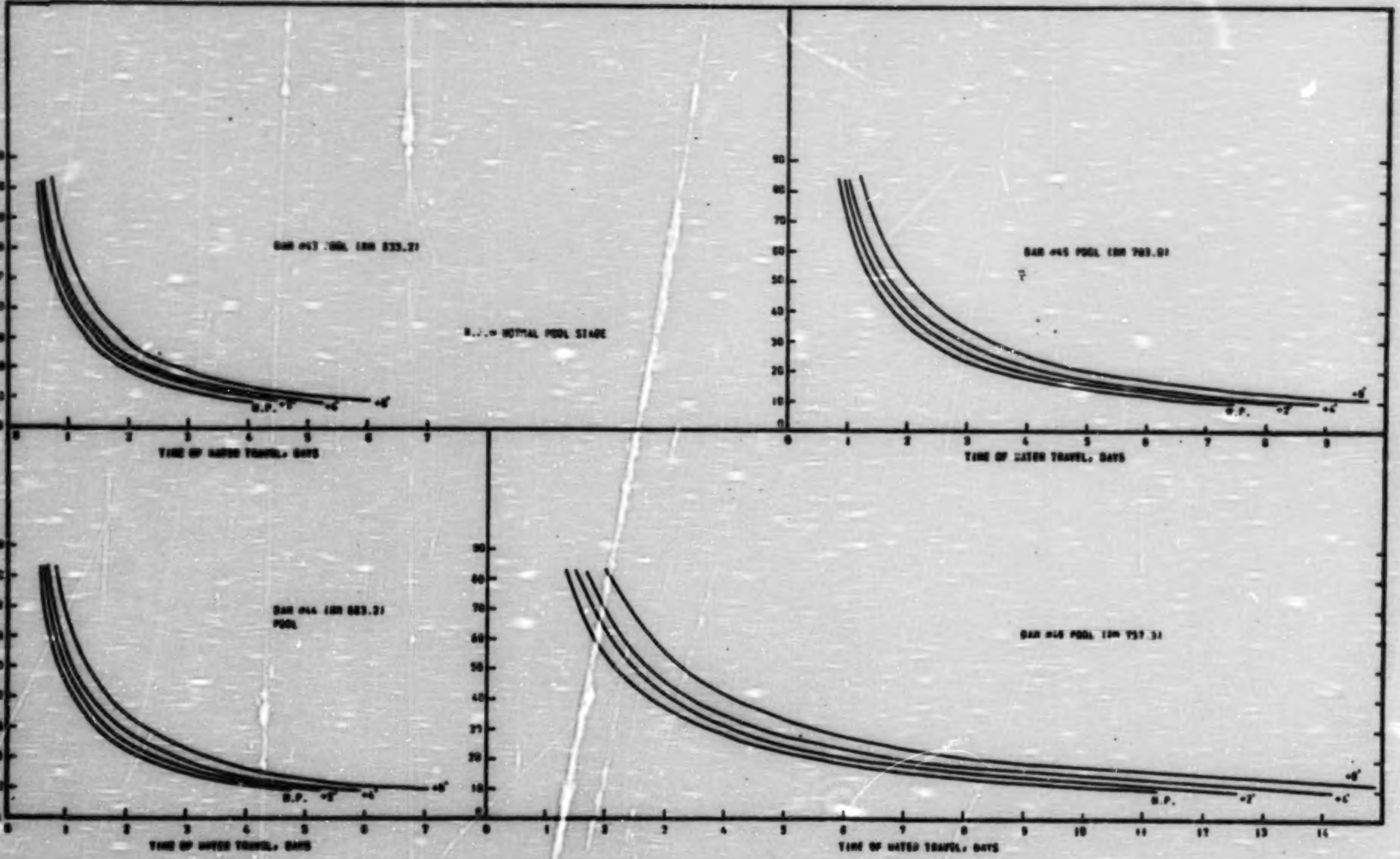
3. Calculations used an average pool elevation. Variations from this assumption must be small (slope of the hydraulic gradeline must be small).

4. Longitudinal dispersion is not significant; plug flow conditions are approached.

These assumptions are reasonably well met in the Ohio River at low flow conditions. Time-of-travel predicted within a given pool should be reasonably accurate. Estimates for the total elapsed time for the 190-mile reach would not be as accurate because of longitudinal dispersion but should yield a good approximation.

The hydraulics of the Ohio River are regulated to a large extent by the operation of the existing navigation dams. The reach examined extends from McAlpine Dam to the Evansville water works. There are five dams in this reach with the most downstream stations affected by a sixth. Depending on the wicket settings at each dam, a flow range can occur for an average pool elevation. Thus, no stable stage-discharge relationship exists on the Ohio River at controlled, low flows. To account for this phenomena, travel times were calculated for 5 flow conditions for 4 separate river stages for each pool. The time-of-travel through each pool is presented as 4 curves representing the 4 river stages assumed which were normal pool, 2, 4 and 8-feet above normal pool. (Figures D-1 and D-2.)

FIGURE D-1
TIME OF WATER TRAVEL
OHIO RIVER: LOUISVILLE, KY. - EVANSVILLE, INDIANA



D-2-a

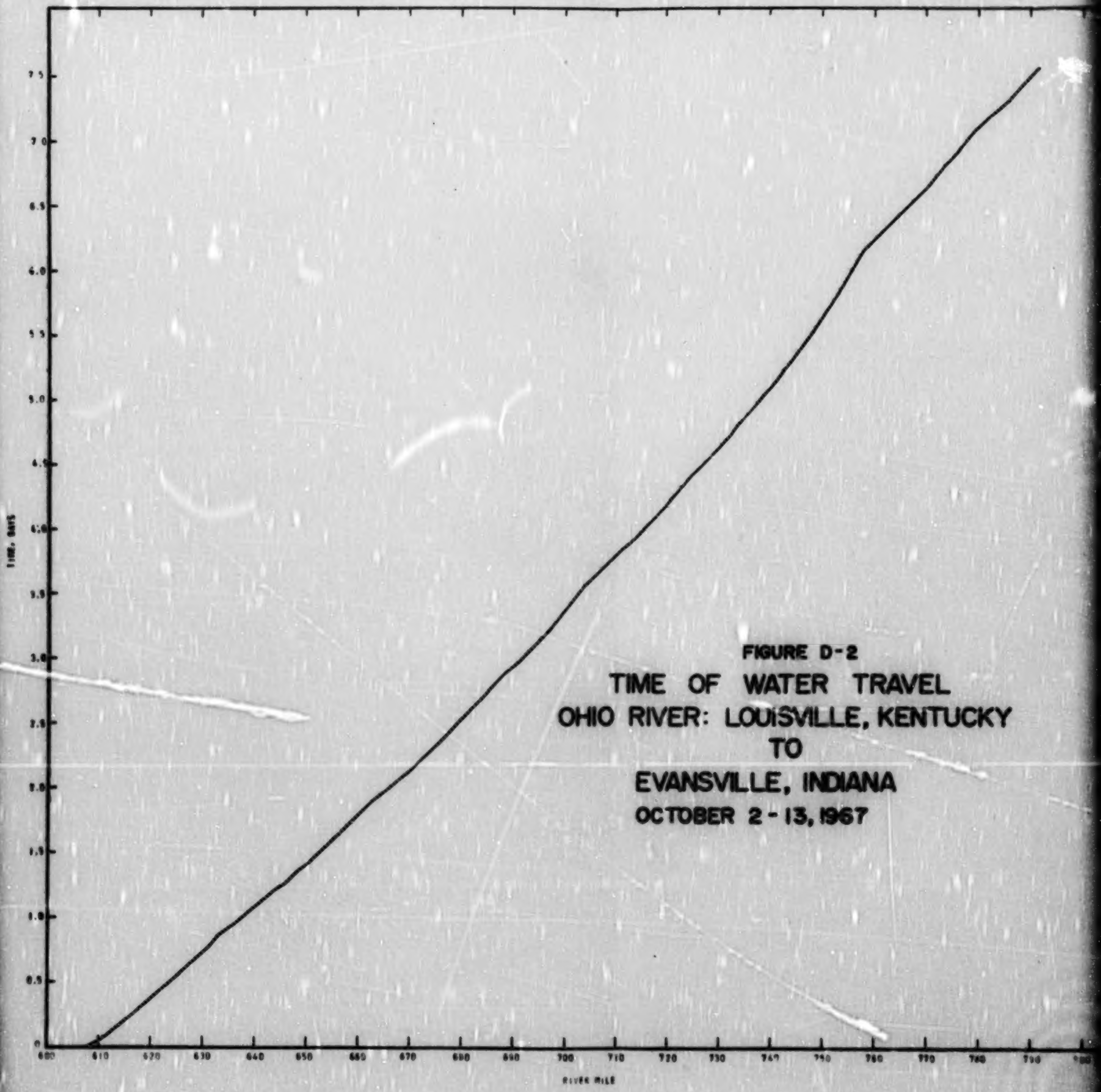


FIGURE D-2

TIME OF WATER TRAVEL
OHIO RIVER: LOUISVILLE, KENTUCKY
TO
EVANSVILLE, INDIANA
OCTOBER 2 - 13, 1967

This presentation method allows determination of time-of-travel for a variety of river conditions by interpolation using these curves.

For the October 2 - 14, 1967 survey period, time-of-travel was calculated for the average stage and flow condition which prevailed. A cumulative travel time-river mile diagram was prepared for this calculation (Figure D-2).

Flow and stages used in this analysis are presented in Table D-1. The travel time downstream from the Louisville STP are presented in the report text.

Table D-1

OHIO RIVER FLOW

October 2-13, 1967

Date	Louisville, Ky.			Evansville, Ind.	
Oct. 67	Corps of Engineers CFS	Geological Survey CFS	Weather Bureau CFS	Corps of Engineers CFS	USGS rating curve CFS
2	68,000	80,300	65,000	88,400	54,600
3	34,000	48,400	37,000	88,200	59,100
4	24,800	43,700	45,000	95,100	46,850
5	45,800	47,200	50,000	62,800	42,600
6	35,500	42,400	40,000	80,400	49,100
7	46,000	48,700	55,000	67,600	44,250
8	45,100	48,200	52,000	63,200	49,000
9	44,100	45,900	45,000	65,700	48,600
10	34,100	41,900	40,000	51,200	44,900
11	31,400	38,000	35,000	54,200	41,400
12	25,100	34,900	30,000	45,400	36,000
13	32,000	34,800	27,000	43,500	35.750
Mean	38,800	46,200	43,416	67,100	45,980
cfs/sq mi	.426	0.507	0.475	0.627	0.430

TABLE D-2

TIME-OF-TRAVEL ANALYSIS

FLOWS USED

		APPROX. DRAINAGE AREA		FLOW			
LOCATION	River Mile	Total Sq.Mi.	Increase Sq.Mi.	cfs	Yield cfs/s.m.	Avg. cfs	Reach Number
McAlpine Dam	607	91,170		46,200	0.507		
Dam #43	633.2	94,800	3,630	47,250	0.498	46,700	1
Dam #44	663.2	95,800	1,000	47,540	0.496	47,400	2
Dam #45	703.0	96,500	700	47,750	0.495	47,640	3
Dam #46	757.3	97,400	500	48,000	0.493	47,880	4
Dam #47	777.7	97,800	400	48,120	0.492	48,060	5
Green River	784.5	97,900	100	48,150	0.492	48,140	6
Evansville	792.3	107,000	9,200	50,790	0.475	50,780	7

		Drainage Area		FLOW		
TRIBUTARIES	River Mile	Of Mouth Sq.Mi.	at Gage Sq.Mi.	at Gage cfs	at Mouth cfs	Yield cfs/s.m.
Salt River	607.3	2,890	1,197	14	35	0.012
Green River	784.5	9,230	7,564	2,190	2,800	0.290

NOTE: Flows downstream from Louisville assuming average yield in this portion of the drainage basin is the same as the Green River drainage basin.

APPENDIX E

OCTOBER 1968 SURVEY

The Evansville, Indiana, Field Station of the Ohio River Basin Project conducted an intensive water quality survey of the Ohio River in the reach from Owensboro, Kentucky to Evansville, Indiana, during the period October 10-17, 1968. Ten river stations were sampled including a station on the Green River (Table E-1). Seven of the ten stations were the same as those used in this reach during the October 1967 survey. Data and descriptions of the survey are available in work Document E-7 available in the Evansville office.

River flows for the sampling days were estimated by the Weather Bureau in the Daily River Forecast and averaged 18,300 cfs at Louisville and 21,700 cfs at Evansville.

Stream temperatures averaged approximately 21° C. at Evansville and 20° C. at Owensboro.

SAMPLING

The sampling routine followed during the survey has been described in an open file report of the field station and is essentially reproduced here. Field data are also contained in this open file report.

Samples from each station were collected each day for a six-day sampling period. The direction of sample collection was alternated between upstream and downstream throughout the survey to obtain samples from each station at various times throughout the day. Samples were taken on November 10 and 11, 1968 and November 14 to 17, 1968.

At mile points 779.1 and 786.8, the river was sampled at three points per cross-section during the entire survey. Mile point 770.0 was sampled at three points per cross-section the last three sampling days. Mile point 759.5 and 765.2 was sampled at three points per cross-section the first three days of the survey. The last three days these two mile points were sampled at five points per cross-section. Mile point 752.8 was three point cross-sectioned three times in the survey. The purpose of the cross-sectioning was to see what degree of lateral mixing was occurring. A three point cross-section at a depth of five feet, for comparison with surface samples, was collected three times at Mile point 759.5 to determine if stratification occurred. Samples at other stations were collected from mid-channel.

Effluent samples from the Owensboro Sewage Treatment Plant and an Owensboro industrial outfall were also collected.

ANALYSES PERFORMED

Of the several analyses performed during the field stations' survey, only the coliform bacteria results will be included here for analyses. These results will be analyzed to show the effects of location and number of sample points for a cross-section. The variation in coliform bacteria densities over the cross-section demonstrates the difficulty in obtaining representative samples in a wide, slow-moving stream such as the Ohio River.

RESULTS

Initial effort was made to mathematically composite data from three points per station and five points per station samples to obtain a single, representative density for each station. This was accomplished by arithmetically averaging the data for each day at a station. The daily average values were then geometrically averaged for each station in accordance with a logarithmic normal distribution. The results of this analysis (Table E-1 and Figure E-1) indicated that densities in the river were greater than could be accounted for by the sewage plant discharge and that perhaps bacterial growth occurred.

Further analysis was directed toward obtaining a more representative average of coliform densities over a cross-section. The first three stations downstream from the Owensboro Sewage Treatment Plant were selected for this special analysis (Stations O-759.5, O-763.2 and O-770.0). The first two stations were sampled at five points over

TABLE E-1

COLIFORM BACTERIA

Owensboro, Ky.-Evansville, Ind.

October, 1968

	TOTAL COLIFORMS MF/100 ml			FECAL COLIFORMS MF/100 ml		
Station	Mean	+ 1 std. dev.	- 1 std. dev.	Mean	+ 1 std. dev.	- 1 std. dev.
0-752.8	7,850	14,500	4,230	44	74	27
0-758.3 (Owensboro STP)	63,650,000	141,000,000	28,700,000	2,600,000	3,250,000	2,085,000
0-759.5	83,200	274,000	25,900	1,940	8,440	450
0-763.2	271,000	428,000	172,000	5,680	13,000	2,490
0-770.0	223,000	458,000	108,000	4,760	8,370	2,710
0-775.1	96,500	247,000	37,300	1,940	3,960	950
0-779.1	114,500	289,000	45,300	1,590	3,520	720
0-784.0	47,400	76,800	29,200	1,290	2,460	680
0-786.8	76,800	237,000	24,900	1,130	2,140	590
0-791.5 (Evansville W.W.)	66,400	291,000	15,100	700	1,550	320

Note: Those stations cross sectioned used arithmetic average to obtain daily composite.

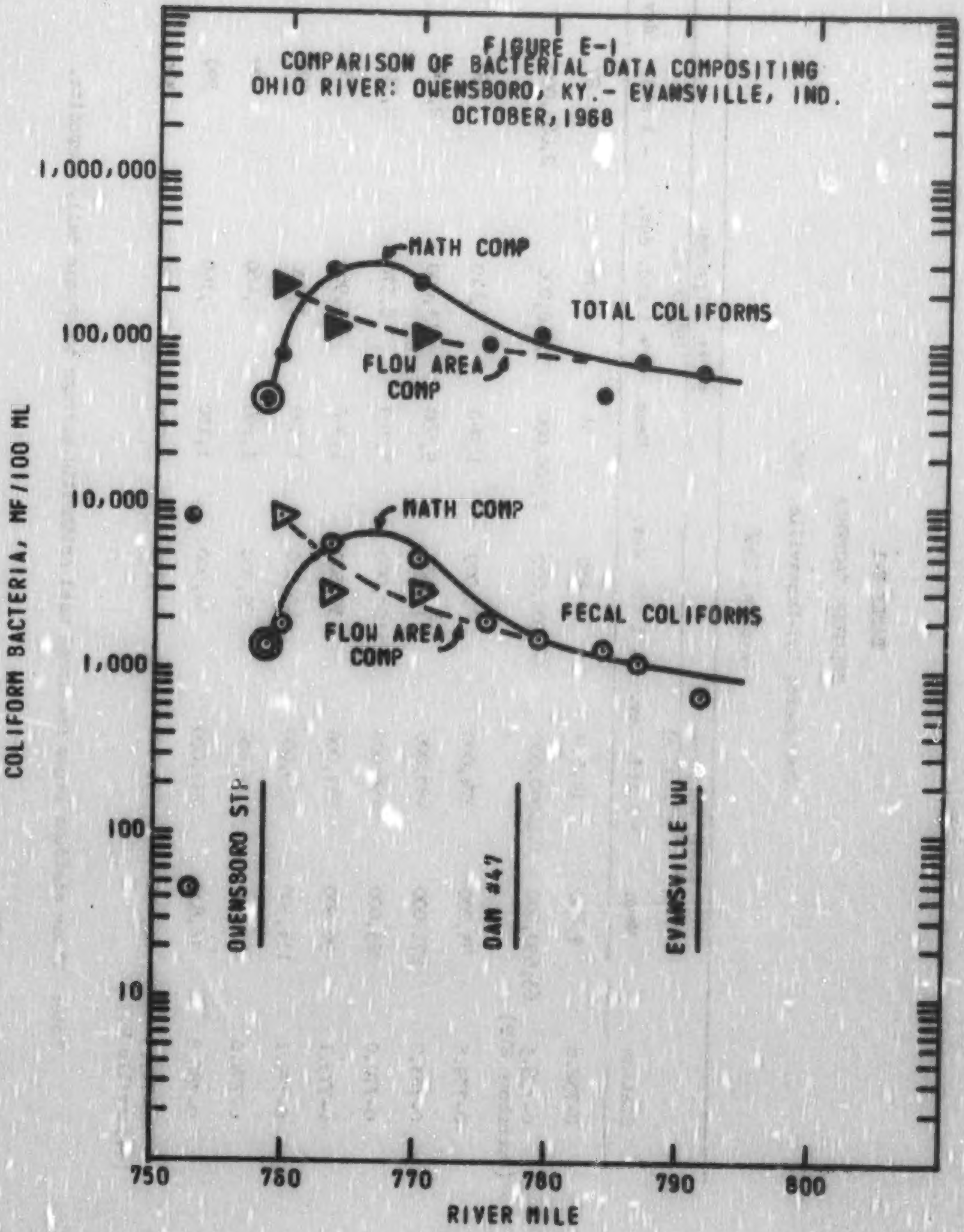


FIGURE E-1
COMPARISON OF BACTERIAL DATA COMPOSITING
OHIO RIVER: OWENSBORO, KY.- EVANSVILLE, IND.
OCTOBER, 1968

the cross-section for the final three survey days. Three day geometric means were obtained for each of the five cross-section points which were then plotted (Figure E-2). The quarter-point samples of Station 0-770.0 were likewise averaged and plotted. To obtain weighted mean densities, the stream cross-section area at each station was plotted and the area represented by each of the cross-section sample points were allocated. The cross section area representing each sampling point was determined with a planimeter.

The mean coliform density for each cross sectional area segment was obtained by finding the area under the coliform curve corresponding to and divided by the distance shown on the cross-sectional area drawing. The coliform means for the entire cross-section were determined by weighting the coliform density in each segment by the area of flow.

Analysis by this method at each of the three stations yielded mean total coliform densities for the final three sampling days of 225,500 MF/100 ml at Station 0-759.5, 119,700 MF/100 ml at Station 0-763.2 and 107,000 MF/100 ml at Station 0-770.0. A similar analysis was conducted for the fecal coliforms with similar results. Mean densities were respectively 8,540 MF/100 ml, 2,960 MF/100 ml and 2,990 MF/100 ml.

The curves plotted through these results indicate a decreasing trend rather than the increasing one determined by the mathematical averaging procedure (Figure E-1). The method using the cross-sectional

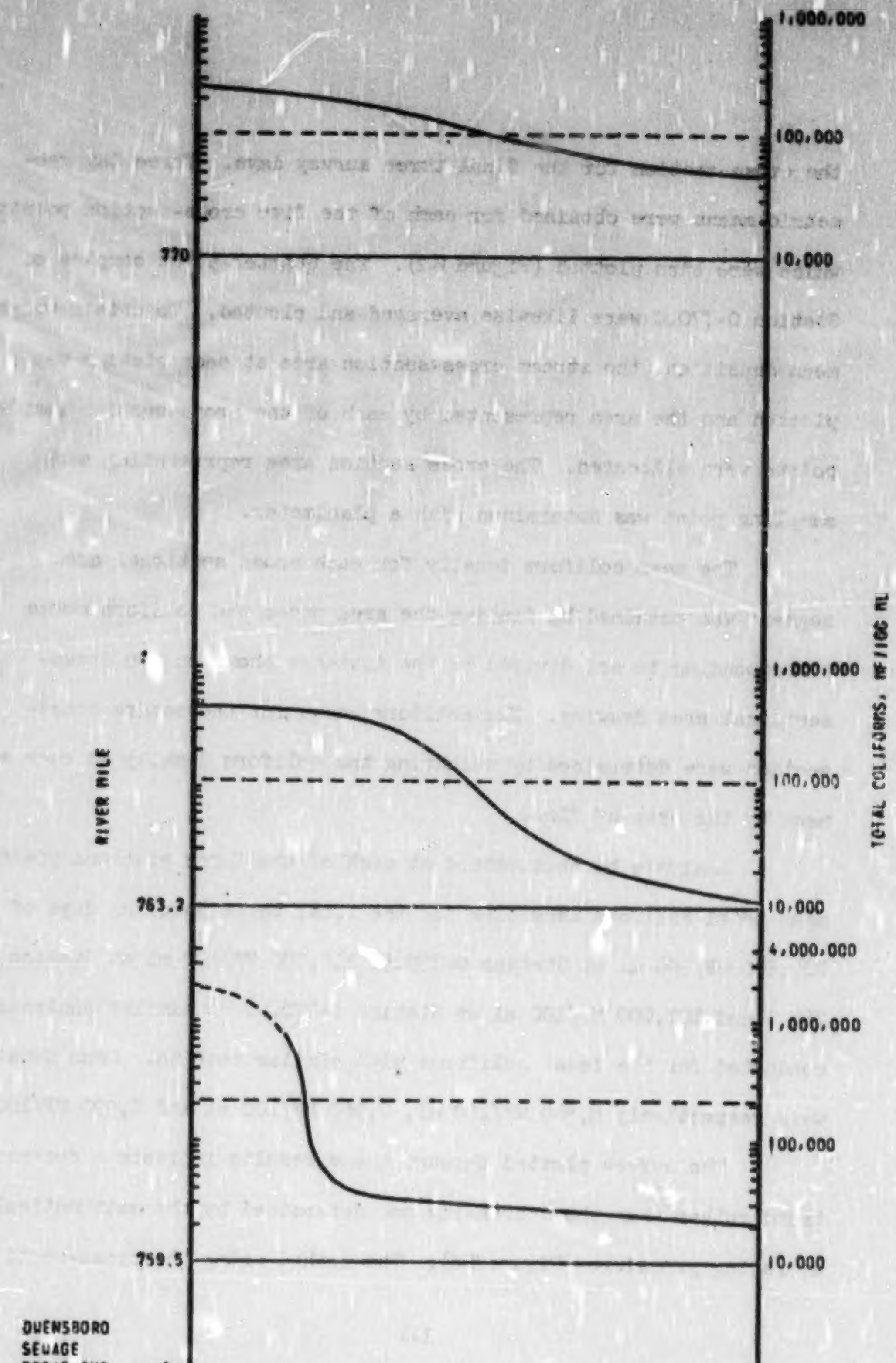


FIGURE E-2
TOTAL COLIFORM DENSITY GRADIENT
OHIO RIVER AT OWENSBORO, KY.
OCTOBER, 1968

areas is the more exact method and the decreasing trend is probably the actual one occurring.

The major difficulty in applying this analysis method is determining the densities from the stream banks to the first sampling points. Definition of this curve section becomes more critical to the analysis as the waste source is approached because of the greater differences in bacterial densities over the section.

Examination of the cross-section coliform density curves for Station 0-759.5 (Figure E-2) which is located only slightly more than one mile downstream from the Owensboro sewage treatment plant discharge illustrates this problem. The curve was first plotted on semilog paper with its compressed scale. The densities thus determined were transferred to arithmetic paper so that the area could be determined. Although this method seemed the most reasonable approach, the derived average would depend upon the judgment of the analyst in defining the original curve.

One pertinent result of this analysis is the demonstration of the difficulty in obtaining truly representative samples in rivers close to sources of wastes before lateral mixing occurs. Use of the quarter-point sample locations (three points) at Station 0-759.5 would result in missing the pollution load almost entirely. However, as lateral dispersion mixes the wastes over the entire cross-section in downstream reaches, the curves determined by either of the two analysis methods would approach one another, yielding equivalent results.

The results of this study clarify the bacterial contamination pattern in the reach between Owensboro and Evansville. These data indicate that Owensboro is a primary source of the high bacterial densities occurring at the Evansville Water Works intake.

APPENDIX F

Ohio River: Louisville, Kentucky-Evansville, Indiana

STATION LOCATION

DESIGNATION	RIVER MILE	DESCRIPTION
0-1	600.6	Near the Louisville Water Company municipal intake.
	601-617	Louisville, Kentucky-New Albany, Indiana metropolitan area.
	607	McAlpine Dam locks.
0-2	612.0	Louisville Sewage Treatment Plant (Ft. Southworth Sewage Treatment Plant).
0-3	618.0	1.2 miles downstream from the Louisville Gas and Electric Company generating plant.
0-4	625.7	Near Fishtown light.
0-4A	629.9-0.2	Mouth of Salt River.
	630	West Point, Kentucky.
	633.2	Dam No. 43.
0-5	633.5	0.3 miles downstream from Dam No. 43.
	637.7	Rock Haven, Kentucky.
	643.4	Olin Mathieson Chemical Corporation plant.
0-6	645.7	Buoy one-half mile upstream from Flippens Run.
	646	Brandenburg, Kentucky.
	648	Mauckport, Indiana.
0-7	650.8	Near Haunted Hollow Light.

Ohio River: Louisville, Kentucky-Evansville, Indiana

STATION LOCATION

DESIGNATION	RIVER MILE	DESCRIPTION
	656	New Amsterdam, Indiana.
	663.2	Dam No. 44.
0-8	663.5	0.3 miles downstream from Dam No. 44
	664	Leavenworth, Indiana.
0-9	667.3	Near Fredonia Light.
	677	Wolf Creek, Kentucky.
0-10	678.2	Near Morrows Daymark-Alton Bar Upper Daymark.
	679	Alton, Indiana
0-11	682.9	Near Rono Light.
	686	Concordia, Kentucky
0-12	689.8	Near Flint Island Light
	692	Derby, Indiana.
0-13	700.9	Upstream from Rome, Indiana-Stephensport, Kentucky.
	701	Rome, Indiana Stephensport, Kentucky.
	703.0	Dam No. 45.
0-14	703.6	0.6 miles downstream from Dam No. 45.
0-15	710.5	One-half mile upstream from Cloverport, Kentucky.
	711	Cloverport, Kentucky.

Ohio River: Louisville, Kentucky-Evansville, Indiana

STATION LOCATION

DESIGNATION	RIVER MILE	DESCRIPTION
0-16	717.2	Near Hog Point Light.
	720.8	Cannelton Locks and Dam (under construction).
0-17	723.5	Near Lincoln Trails Highway Bridge.
	724	Hawesville, Kentucky. Cannelton, Indiana.
0-18	726.4	Near Maxon Dock Light.
	727	Tell City, Indiana
0-19	730.0	Near entrance of Henderson Creek.
	731	Troy, Indiana.
0-20	736.6	Corn Island Light and Daymark.
	738	Lewisport, Kentucky.
0-21	741.3	Near entrance of Little Sandy Creek.
	742	Grandview, Indiana.
	747	Rockport, Indiana.
0-22	752.8	Near Yellow Bank Island Light.
	753-759	Owensboro, Kentucky metropolitan area.
	757.3	Dam No. 46.
0-23	758.3	Owensboro, Kentucky sewage treatment plant.
0-24	763.0	0.2 miles upstream from Enterprise, Indiana.

Ohio River: Louisville, Kentucky-Evansville, Indiana

STATION LOCATION

DESIGNATION	RIVER MILE	DESCRIPTION
	763.2	Enterprise, Indiana.
0-25	769.8	Near French Island lower Light and Daymark.
	776.0	Newburgh Dam (under construction).
	777.7	Dam No. 47.
	778	Newburgh, Indiana.
0-26	778.1	0.4 miles downstream from Dam No. 47.
0-27	784.0	0.3 miles upstream from entrance of Green River.
G-28	784.3-0.2	Mouth of Green River.
0-29	786.8	Near twin highway bridges.
0-30		Near Water Works Light (Evansville, Indiana).

APPENDIX G

SUMMARY TABLE
OHIO RIVER SURVEY
LOUISVILLE, KENTUCKY-EVANSVILLE, INDIANA

October 9-13, 1967

STATION DESIGNATION	STATION RIVER MILE	TEMP. °C	pH UNITS	SPECIFIC CONDUCTANCE µmho/cm.	TURBIDITY UNITS	SUSPENDED SOLIDS TOTAL mg/l	SUSPENDED SOLIDS VOLATILE mg/l	BOD 2-DAY mg/l	BOD 5-DAY mg/l	DO mg/l	NITROGEN SERIES AS N ORGANIC mg/l	NITROGEN SERIES AS N NH_3 mg/l	NITROGEN SERIES AS N NO_3 mg/l	PHOSPHATES AS P SOLUBLE mg/l	PHOSPHATES AS P TOTAL mg/l	TOTAL COLIFORMS MF/100 ML	FECAL COLIFORMS MF/100 ML.
0-2	600.6	20	7.3	520	13	19	< 4	1.1	2.5	5.9	1.0	0.5	1.1	0.06	0.08	1,640	1,130
0-3	618.0	20	7.3	530	15	11	< 4	1.3	2.0	6.5	1.0	< 0.4	1.2	0.06	0.08	760,000	89,000
0-4	625.7	20	7.3	520	15	11	< 3	1.0	1.6	6.6	0.9	< 0.2	1.2	0.05	0.09	395,000	30,000
0-5	633.5	20	7.4	530	20	20	4	1.0	1.7	7.2	0.9	< 0.3	1.3	0.06	0.12	485,000	53,800
0-6	643.7	20	7.4	530	24	27	4	0.9	1.5	7.3	0.8	< 0.3	1.3	0.05	0.11	343,000	33,100
0-7	650.8	20	7.4	530	33	34	6	1.0	1.8	7.1	0.8	< 0.3	1.3	0.05	0.13	425,500	49,400
0-8	663.5	20	7.4	520	30	32	< 6	0.9	1.7	7.7	0.9	< 0.2	1.1	0.05	0.11	246,000	25,000
0-9	677.3	20	7.4	530	26	25	4	1.0	1.7	7.4	1.0	< 0.2	1.2	0.05	0.12	241,000	21,400
0-10	678.2	20	7.4	530	21	21	4	0.9	1.5	7.4	0.8	< 0.2	1.2	0.05	0.08	72,300	8,490
0-11	682.9	20	7.5	540	25	23	5	0.8	1.4	7.3	0.8	< 0.3	1.2	0.05	0.09	76,800	7,940
0-12	690.8	20	7.5	530	24	16	3	0.8	1.5	7.2	0.8	< 0.3	1.2	0.05	0.10	71,500	6,950
0-13	700.9	19	7.5	530	17	13	< 3	0.9	1.5	7.2	0.8	< 0.2	1.2	0.05	0.08	35,400	3,240
0-14	703.6	$19^{(1)}$	7.5	520	31	26	< 5	0.5	1.1	7.0	0.7	< 0.3	1.2	0.08	0.10	50,000	3,930
0-15	710.5	$19^{(1)}$	7.4	530	30	21	6	0.5	0.9	7.3	0.8	0.3	1.1	0.07	0.09	41,400	2,540
0-16	717.2	$19^{(1)}$	7.5	530	34	25	6	0.5	1.0	7.4	0.7	0.2	1.2	0.06	0.09	38,150	2,540
0-17	723.5	$19^{(1)}$	7.5	530	24	14	< 4	0.5	1.0	7.3	0.7	< 0.2	1.2	0.07	0.09	21,600	1,730
0-18	726.4	$19^{(1)}$	7.5	540	30	26	6	0.4	0.9	7.2	0.8	< 0.3	1.1	0.07	0.09	28,500	1,750
0-19	730.0	$19^{(1)}$	7.5	540	35	25	5	0.5	1.1	7.3	0.9	< 0.3	1.1	0.07	0.09	24,900	1,490
0-20	736.6	$19^{(1)}$	7.4	540	33	23	6	0.6	1.0	7.4	0.7	< 0.2	1.1	0.05	0.08	26,400	1,660
0-21	741.3	$19^{(1)}$	7.5	530	31	17	6	0.6	1.1	7.3	0.7	0.3	1.1	0.06	0.08	20,200	1,460
0-22	752.8	$19^{(1)}$	7.6	540	29	16	5	0.5	1.0	7.3	0.8	0.3	1.1	0.08	0.09	15,600	700
0-24	763.0	$19^{(1)}$	7.5	550	33	21	< 6	0.6	1.1	7.9	0.9	0.3	1.1	0.07	0.10	19,400	940
0-25	769.8	$19^{(1)}$	7.5	550	34	25	6	0.7	1.2	7.9	0.8	0.3	1.0	0.07	0.10	15,300	770
0-26	778.1	$19^{(1)}$	7.6	530	36	21	6	0.5	1.2	8.2	0.9	0.3	1.0	0.08	0.10	28,700	1,380
0-27	784.0	$19^{(1)}$	7.6	550	29	17	< 6	0.6	1.2	8.2	0.9	0.3	1.0	0.07	0.10	33,900	1,230
0-29	785.8	$19^{(1)}$	7.6	530	33	18	6	0.8	1.6	8.2	0.8	< 0.3	1.0	0.08	0.10	32,600	940
0-30	791.5	$19^{(1)}$	7.6	550	38	29	< 6	0.7	1.4	8.1	0.9	< 0.3	1.0	0.08	0.12	27,700	1,010
Tributary Streams																	
Salt River	629.9-0.2	20	7.4	530	15	15	< 5	1.3	2.1	4.7	1.0	0.5	1.2	0.09	0.16	1,640,000	112,000
Green River	784.3-0.2	20	7.8	430	34	20	6	0.5	0.8	7.6	0.7	< 0.1	0.6	0.02	0.02	580	18
Sewage Treatment Plant Effluents																	
Louisville	610.0	-	7.4	-	250	128	74	112	167	-	10.5	16.5	< 0.1	6.4	8.9	63,700,000	11,100,000
Owensboro	758.3	-	7.1	760	170	99	84	71	121	-	7.6	17.0	< 0.2	8.7	10.0	70,100,000	3,930,000

NOTE: Difference in thermometers used between upstream section crews and downstream section crews of 1 degree centigrade.
Downstream temperature readings were increased by 1 degree centigrade.